Repeatability and Reproducibility Analysis of the ES-2re Dummy in the Sled Test Environment

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1 OBJECTIVE

The purpose of this project is to evaluate the repeatability and reproducibility (R&R) of the ES-2re dummy's responses in the sled test environment. To achieve this goal, two ES-2re dummies were subjected to a series of Hyge sled tests at TRC of Ohio, Inc.

2 METHODS

In an attempt to reduce test-to-test variation of sled pulse parameters, VRTC utilized a recently developed Dual Occupant Side Impact sled buck (see Figure 1). This allowed for two dummies to be tested simultaneously, insuring that the dummies were subjected to the same sled pulse for a given test.

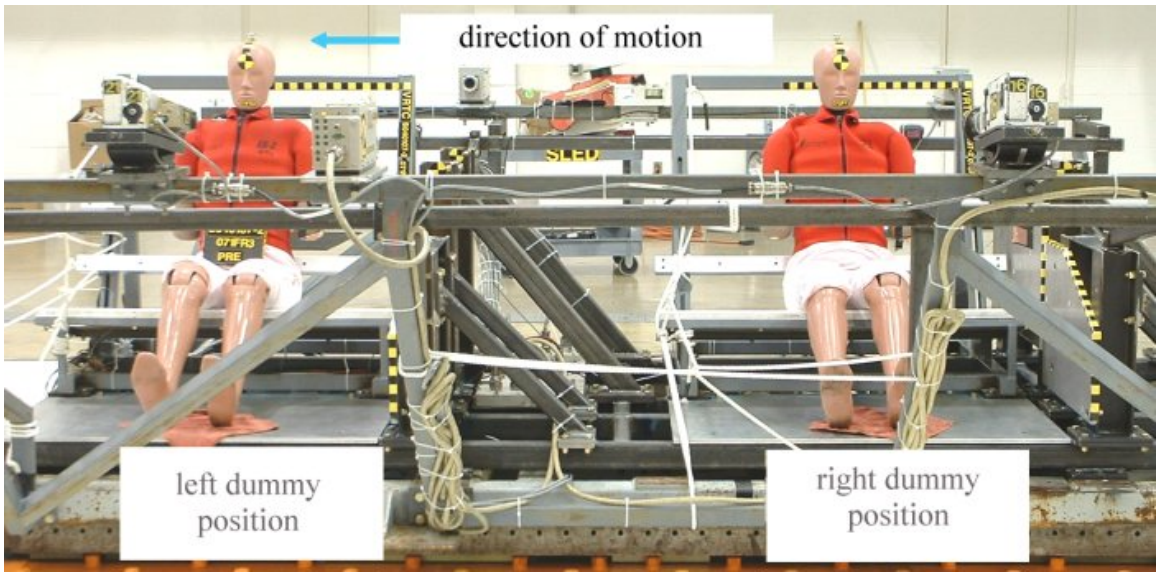

Figure 1.

2.1 Test Matrix

Two ES-2re dummies were selected for the evaluations: serial numbers 070 and 071. Two test conditions were utilized for the R&R assessment with the pertinent parameters summarized in Table 1.

Table 1. ES-2re R&R Sled Test Matrix

Wall Configuration	Wall Condition	Impact Speed (m/s)	Quantity
Flat Wall	Rigid	6.7	5
Abdomen Offset	Rigid	6.7	5

2.2 Sled Buck Description

The sled buck incorporated a Teflon-covered bench seat with two Teflon-covered rails to support each dummy from behind (Figure 2). As the sled buck was accelerated, the buck slid beneath the dummies until they impacted the rigid wall, with the dummies' left side making contact. In order to obtain the desired wall impact speed and to insure that the buck had achieved a constant velocity prior to dummy-to-wall impact, each dummy was pre-positioned on the Teflon-covered bench at a the same distance from the wall. For the flat wall tests, the dummies were positioned with the struck-side arms down such that the

arm would make first contact with the wall. The dummies were placed such that the point of first contact on the arm was 13 inches away from the wall. During the abdomen offset tests, the dummies were positioned with their arms up so that the abdomen would make first contact with the offset block. In this configuration, the dummies were positioned such that the point of first contact on the abdomen was 13 inches away from the offset block. The individual pre-test measurements performed for each test are summarized in Appendix A in Tables A.1. and A.2.

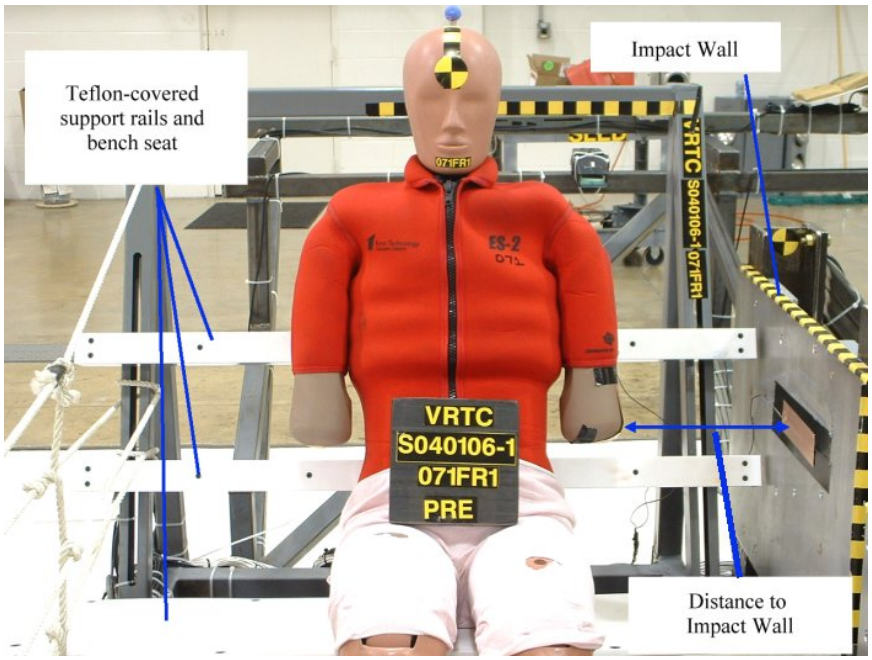

Figure 2. Flat wall test setup

For the flat wall test condition, the wall was 374 mm high from the front edge of the seat, and 368 mm long from the back of the seat, as shown in Figure 3. For the abdomen offset test condition, the same flat wall was used, with a three-inch-thick wooden offset block attached to the wall (Figure 4). The dimensions of the offset block are contained in Figure A.1 in Appendix A. Figure 5 shows a photo of the pre-test setup for the abdomen offset tests. The offset block was oriented such that it would impact the abdomen only, above the pelvis and below the lower rib. The objective of the abdomen offset tests was to provide a test environment with severe loading of the abdominal region.

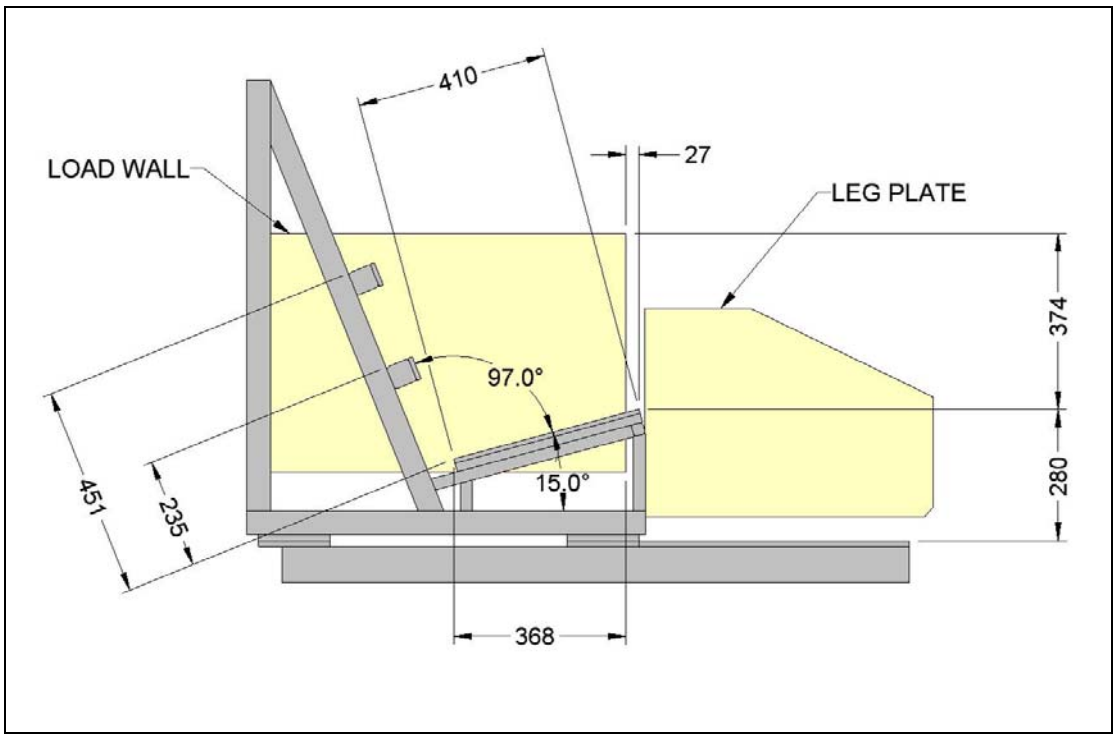

Figure 3. Flat wall setup dimensions

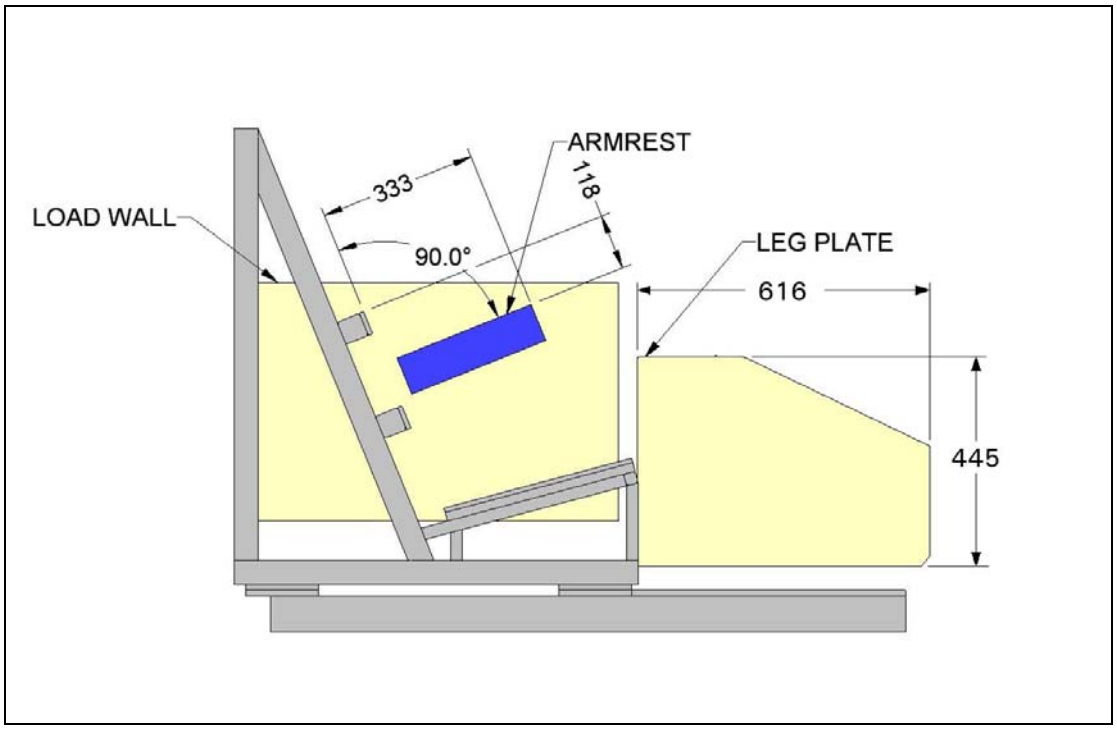

Figure 4. Abdomen offset setup dimensions

Figure 5. Abdomen offset test setup

2.3 Sled Pulse

The sled pulse, which was the same for each of the test conditions, was an approximate half-sine wave, with the peak acceleration of 12.7 g's and duration of approximately 80 ms. Figures B.1 and C.1 in Appendix B and C, respectively, show overlays of the repeated sled acceleration data traces for each test condition. Figures B.2 and C.2 show overlays of the repeated sled velocity data traces for each test condition. Data was collected at 12,500 Hz.

2.4 Instrumentation

Instrumentation used in the two dummies during sled tests is shown in Table 2. High-speed digital video cameras were positioned in front of each dummy in order to capture head motion for use in performing motion analysis of the head translation. The dummies were instrumented to measure the responses of the primary body segments, including the head, neck, shoulder, thorax, abdomen, lumbar spine and pelvis. A contact switch was positioned on the side of each dummy and on the load wall at the location of first contact to indicate the precise instant of dummy contact with the wall.

2.5 Data Filtering

Data was filtered according to SAE J211, except for several injury criteria measures which required a different filter class. Filter classes used are summarized in Table 2.

Table 2. Instrumentation for ES-2re R&R Sled Series

	Location	Measurement	Direction	CFC	channels per dummy	Total # channels per test
Dummy	Head	Acceleration	X, Y, Z	1000	9	74
	Upper Neck	Force	X, Y, Z	1000	3	
		Moment	X, Y, Z	600	3	
	Shoulder	Force	Y	1000	1	
	Upper Spine (T01)	Acceleration	X, Y, Z	180	3	
	Lower Spine (T12)	Acceleration	X, Y, Z	180	3	
	Ribs	Displacement	Y	180	3	
		Acceleration	Y	1000	3	
	Lumbar	Force	Y	1000	1	
		Moment	X	1000	1	
	Abdomen	Force	Y	600	3	
	Pubic Symphysis	Force	Y	600	1	
	Pelvis	Acceleration	X, Y, Z	1000	3	
Sled	Sled	Acceleration	X	60	1	4
	Sled	Velocity	X	180[1]	1	
	Load Wall	Event	N/A	N/A	2	
TOTAL						**78**

[1] Sled acceleration is filtered at CFC 180 before integration for sled velocity.

2.6 Head Motion Analysis

Analysis of the dummies' head motion was also conducted using the high-speed digital video from each test. The objective was to determine if the dummies' head motion was repeatable and reproducible. The following procedure was used to analyze the high-speed digital video (reference Fig. 6):

1. The prominent target (labeled "origin") located in the lower right corner of Figure 6 was selected as the origin reference. The target was given coordinates of (0,0).
2. The target located on the dummy's forehead (labeled "target") is used to set the scale for the motion analysis – the target is known to be 50.8 mm in diameter.
3. The location of the target relative to the origin is tracked using the Image Express Motion Analysis software. The analysis begins at the time of the dummy's first contact with the wall and continues beyond the point of maximum head lateral excursion. In the case of the abdomen offset sled tests, the dummy does not rebound due to the underside of the arm hooking onto the top of the impact wall. This action occurs well after the peak loading responses have been registered. Therefore, the analysis is stopped at 75 ms, just prior to the instant at which the arm hooks onto the wall.
4. The peak y- and z-displacements are computed by subtracting the initial position of the target from its final position (reference Figure 7).

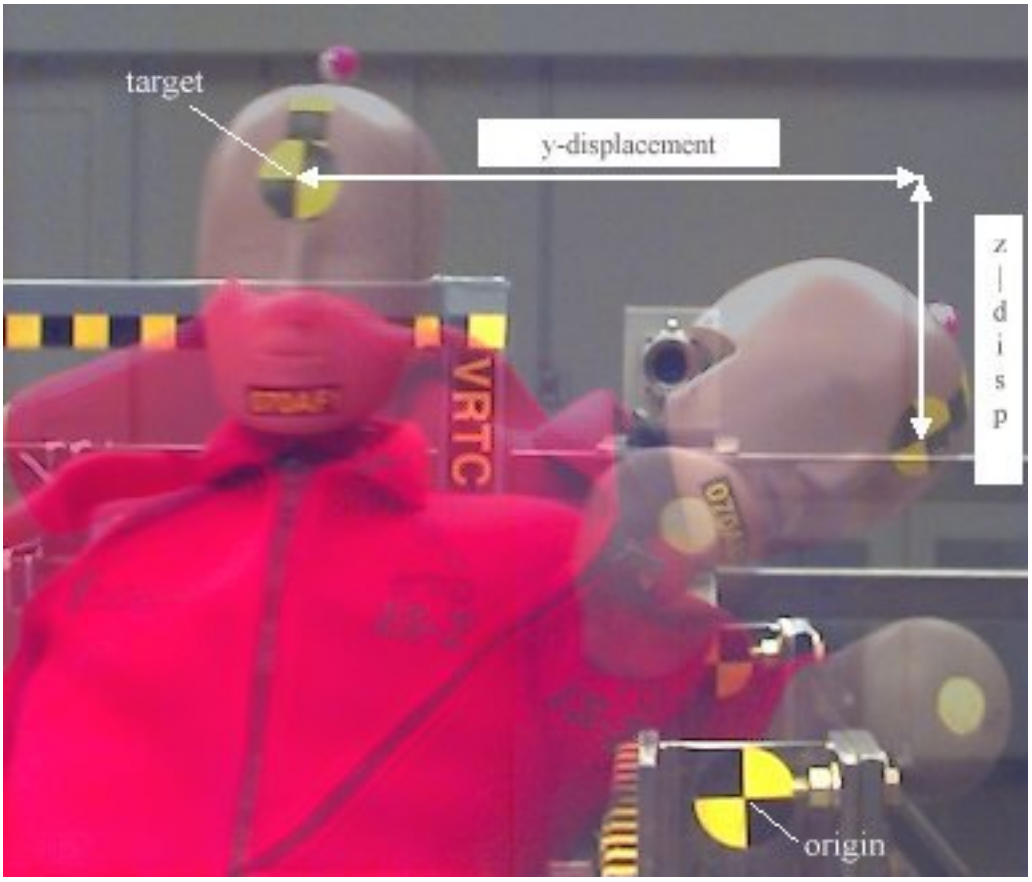

Fig. 6. Definition of y- and z-displacements for head motion analysis.

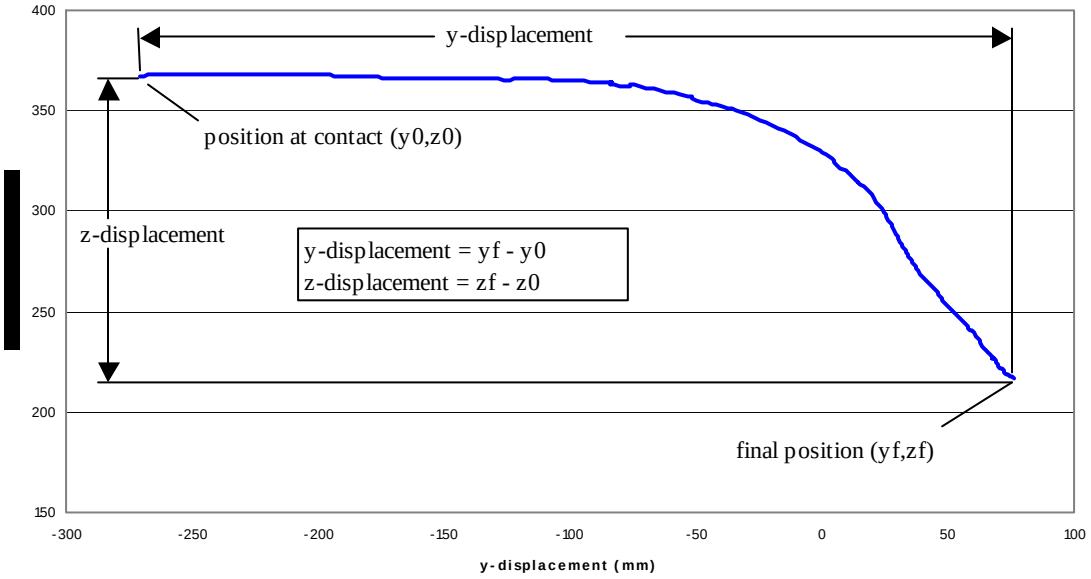

Figure 7. Computations for y- and z-displacements

3 RESULTS

3.1 Flat Wall Test Series

Table B.1 in Appendix B contains a complete summary of the peak responses for each test in the flat wall and abdomen offset test series, respectively. Table 4 contains a summary of the coefficient of variation (%CV) values for the R&R analysis for the five flat wall tests. The dummy rating practice set forth in ISO/TC22/SC12/WG5 indicates that a CV less than 5% is considered excellent; above 5% is good and as the CV approaches 10% it becomes borderline acceptable. Any CV above 10% is considered poor. Note that the tables have been color-coded: green indicates that the %CV was less than 5%; yellow indicates the %CV was between 5 and 10%; and pink indicates greater than 10%.

Table 4. %CV Values for Flat Wall Sled Test Responses

		Dummy SN	070	071	both
Location	**Measurement**	**Direction**	%CV	%CV	% CV
Head CG	Acceleration	Y	4.2	3.0	8.4
		Z	1.0	1.9	3.6
		Resultant	1.0	1.9	6.7
	HIC-36	Resultant	2.8	3.2	3.4
Head	Displacement (Front Camera)	Lateral	3.5	2.3	3.7
		Vertical	3.4	4.5	6.8
		time	3.3	2.1	2.8
Upper Neck	Force	Y	2.1	1.9	2.4
		Z	1.9	1.9	4.6
	Moment	+X	8.2	3.0	6.3
		-X	7.9	1.5	8.3
		-Y	3.3	5.7	4.5
		+Z	4.2	4.3	4.2
Shoulder	Force	Y	5.9	3.4	9.8
T1	Acceleration	Y	1.5	2.4	5.7
		Resultant	4.8	2.2	5.0
T12	Acceleration	Y	4.0	2.8	5.7
		Resultant	3.8	2.8	5.3
Upper Rib	Displacement	Y	1.9	2.2	9.0
Middle Rib	Displacement	Y	0.7	1.3	5.0
Lower Rib	Displacement	Y	0.9	0.9	2.6
Abdomen-Front	Force	Y	7.8	4.6	7.0
Abdomen-Center	Force	Y	7.4	4.8	6.4
Abdomen-Rear	Force	Y	6.9	4.6	9.4
Abdomen-Sum	Force	Y	6.0	4.5	5.9
Lumbar	Force	Y	14.8	10.0	17.5
	Moment	+X	3.2	1.8	4.1
Pubic Symphysis	Force	Y	4.2	3.3	4.7
Pelvis	Acceleration	Y	7.3	4.8	5.8
		Resultant	3.8	4.7	4.1
Sled	Acceleration	X	0.4	0.4	0.3
Sled	Velocity	X	0.2	0.2	0.2

In general, the responses in the flat wall tests displayed either excellent or good repeatability and reproducibility. Appendix A contains plots that describe the responses for both dummies in the flat wall test condition. The following discussion will focus on the responses that are identified as proposed injury criteria by Kuppa (2004). Note that in the interest of brevity, the following shorthand has been utilized to represent repeatability and reproducibility values: CV_{70} and CV_{71} represent the CV values for the repeatability of dummy's 070 and 071, respectively; and CV_{both} represents the CV value for the reproducibility of both dummies 070 and 071.

3.1.1 Sled Pulse Parameters

The peak sled acceleration and peak sled velocity provided extremely repeatable and reproducible test conditions with %CV values less than 0.5% for all tests. This was important to insure minimal test-to-test variations.

3.1.2 Head Responses

The head acceleration responses were of low magnitude as there was no head contact occurring during the event. The proposed injury criteria limit for HIC_{36} is 1000; the average HIC_{36} response for both dummies was only 51.9. Despite the low magnitude of the response, the HIC_{36} responses exhibited excellent repeatability of each dummy and reproducibility of both dummies (CV_{70}=2.8; CV_{71}=3.2; CV_{both}=3.4).

3.1.3 Spine Accelerations

The upper spine resultant acceleration (T1) provided responses with %CV values equal to or less than 5% for repeatability of each dummy and reproducibility of both dummies (CV_{70}=4.8; CV_{71}=2.2; CV_{both}=5.0).

The average responses of the lower spine resultant acceleration (T12) were below the proposed injury criteria (mean response of both dummies = 57.5 g; proposed injury criteria = 82 g). The repeatability of the dummies' individual response was each considered excellent (CV_{70}=3.8; CV_{71}=2.8), while the reproducibility of the response was just slightly above 5% (CV_{both}=5.3%).

3.1.4 Rib Displacements

The proposed injury criterion is 35 – 44 mm of maximum rib displacement (corresponding to 50% risk of AIS 3+ injury). In this series of tests, all of the ribs had peak displacements greater than 35 mm, an indication of the severity of the test conditions. In all tests, the rib displacement time history provided a smooth response, with no indications of the flat topping phenomena that has been a shortcoming of previous versions of the EuroSID dummy.

Upper Rib Displacements

For each dummy, the maximum upper rib displacement provided excellent repeatability (CV_{70}=1.9; CV_{71}=2.2). The reproducibility of the responses was higher, but still below 10% (CV_{both}=9.0).

Middle Rib Displacement
The repeatability and reproducibility of the maximum middle rib displacement were all less than or equal to 5% (CV_{70}=0.7; CV_{71}=1.3; CV_{both}=5.0).

Lower Rib Displacement
Similarly, the repeatability and reproducibility of the maximum lower rib displacement were also considered excellent (CV_{70}=0.9; CV_{71}=0.9; CV_{both}=2.6).

3.1.5 Abdominal Load
To compute the total abdominal load, the time-history responses of the individual abdominal load cells – the front, center, and rear – are summed. The maximum abdominal load is the peak of this summation over time, i.e. the maximum abdominal load is not equal to the sum of the individual peaks for each load cell.

For all of the tests, the peak abdominal loads were safely below the proposed injury level of 2.4 – 2.8 kN. The repeatability of the maximum abdominal load responses for dummy #071 was less than 5% (CV_{71}=4.5), while the repeatability of dummy #070 and the reproducibility of both dummies were just slightly greater than 5% (CV_{70}=6.0; CV_{both}=5.9).

3.1.6 Pubic Symphysis Load
The peak pubic symphysis loads were well below the proposed injury level of 6.0 kN for all tests. The repeatability and reproducibility of the maximum pubic symphysis loads were all less than 5% (CV_{70}=4.2; CV_{71}=3.3; CV_{both}=4.7).

3.1.7 Other Responses
The head displacements as measured in the high-speed digital video analysis were of particular interest. The peak lateral displacement proved to be very repeatable and reproducible (CV_{70}=3.5; CV_{71}=2.3; CV_{both}=3.7). The peak vertical displacement was also very repeatable (CV_{70}=3.4; CV_{71}=4.5), while the reproducibility was slightly higher than 5% (CV_{both}=6.8). The time of peak excursion also exhibited excellent repeatability and reproducibility (CV_{70}=3.3; CV_{71}=2.1; CV_{both}=2.8). These results indicate that the motion of the head was extremely consistent for all of the tests.

The responses of the lateral lumbar shearing force resulted in CV values greater than or equal to 10% for both repeatability and reproducibility (CV_{70}=14.8; CV_{71}=10.0; CV_{both}=17.5). While these CV values are relatively high, it should be noted that there was no apparent impact on the responses of the pelvis, abdomen, or thorax.

All other responses analyzed provided CV values less than 10% for both repeatability and reproducibility.

3.2 Abdomen offset Test Series
Table C.1 in Appendix C contains a complete summary of the peak responses for each test in the flat wall and abdomen offset test series, respectively. Upon thorough review of the response curves after the test series had been completed, it was observed that the first

test in the series (test #S040109-1) exhibited responses that were somewhat different than the responses observed in the remaining four tests. When compared to the final four tests, the first test had much lower abdominal and lumbar loads and larger rib displacements (reference Figures C.10 – 18 in Appendix C).

Additional analysis was performed in attempt to determine if any possible changes in test conditions could have led to the unique results observed in the first abdomen offset sled test. Table 5 below summarizes the speed of the buck at the time of first contact between the dummy and the wall. From this table it can be observed that the repeatability of the sled pulse and resulting speed at impact was excellent. Furthermore, the buck speed in the first test was not significantly different than that in the final four tests.

Table 5. Buck Speed at Instant of Dummy/Wall Contact

	Buck Speed at Contact (m/s)	
Test No	#070	#071
S040109-1	6.674	6.692
S040112-1	6.697	6.706
S040112-2	6.681	6.706
S040113-1	6.717	6.714
S040113-2	6.694	6.703
avg	6.693	6.704
std dev	0.0166	0.0079
%CV	0.247	0.119

Next, using the data obtained from the dummy/wall contact switch, the instant in time of first contact was analyzed (Table 6). Note that times are relative to the sled's time zero, which is defined by the instant at which the sled first exceeds 0.5 g's. Although the statistical analysis indicates that the time of contact was quite repeatable, the time of contact in test #S040109-1 was 2 to 2.5 ms earlier than that observed for the other 4 tests. This observation has two potential causes: 1) the sled buck was traveling faster beneath the dummies in the first test; or 2) the dummies were seated closer to the wall in the first test. Table 5 above indicates that the buck was not traveling any faster at the instant of dummy contact and Table A.2 in Appendix A indicates that the pre-test measurements for dummy seating were not unusual. Thus, the significance of this observation is not clear.

Table 6. Time of Dummy/Wall Contact

	Time of Dummy Contact (ms)	
Test No	#070	#071
S040109-1	92.64	91.84
S040112-1	94.40	93.68
S040112-2	94.56	94.24
S040113-1	94.80	93.68
S040113-2	94.40	94.08
avg	94.160	93.504
std dev	0.8653	0.9623
%CV	0.919	1.029

Finally, qualitative analysis of the high-speed digital video was conducted to examine the dummy's position and orientation at the instant of impact. For each test, a digital picture of the dummy was captured at the instant of contact between the dummy's abdomen and the offset block. Figure 8 is an overlay figure of the 5 tests - the dummy's position at the time of wall impact for each test has been superimposed in layers over top of each other. Although the picture seems to be a single blurry picture of one dummy, it is actually a fusion of 5 pictures. Some small differences in arm position were noted, however, the analysis revealed that the position of the arm in the first test was roughly in the median position for all five of the tests (i.e. the arm position in the first test was neither the highest nor the lowest for all five tests). This analysis, admittedly qualitative, provides strong evidence that the dummy impacted the wall in nearly the same orientation for each of the 5 tests.

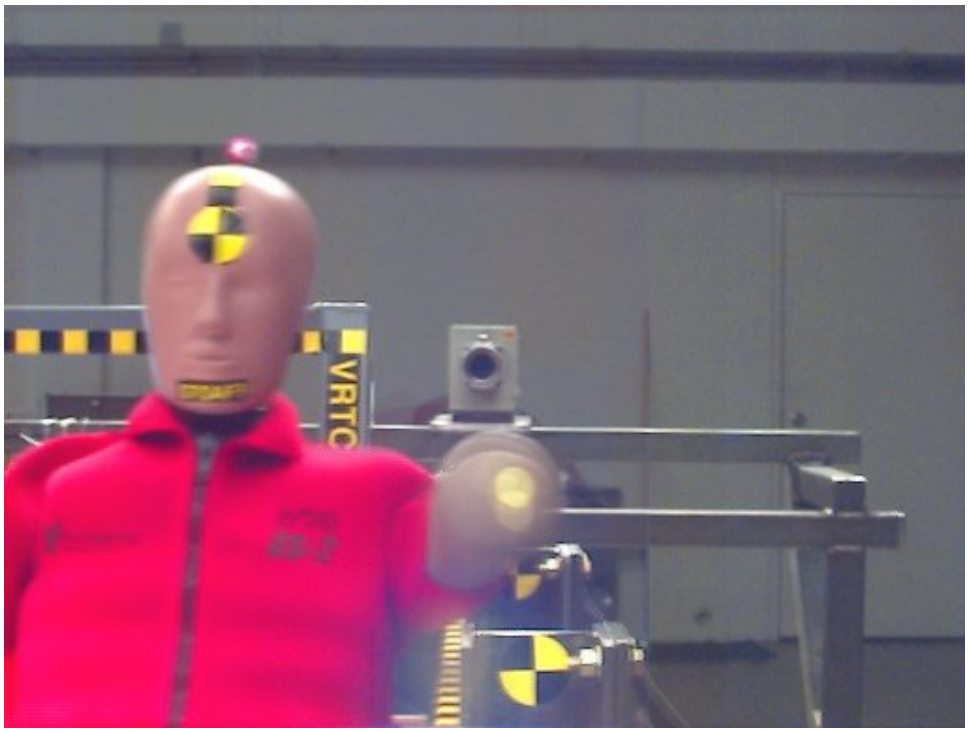

Figure 8. Overlay plot of dummy position at impact in five abdomen offset tests.

Review of the available data provided no indications of any significant difference in the dummy's impact speed, initial position, or orientation with respect to the impact wall at the instant of contact. However, it is apparent that a number of the responses for the first test are unique. Therefore, the R&R analysis conducted for the abdomen offset test series only accounts for the final four tests conducted. Table 7 contains a summary of the coefficient of variation (%CV) values from the R&R analysis for the final four abdomen offset tests.

The majority of the responses for the abdomen offset sled tests provided either excellent or good repeatability and reproducibility. Appendix C contains plots which describe the responses for both dummies in the abdomen offset sled test condition.

Table 7. %CV Values for Final Four Abdomen offset Sled Test Responses

		Dummy SN	070	071	both
Location	**Measurement**	**Direction**	%CV	%CV	% CV
Head CG	Acceleration	Y	1.6	4.6	4.3
		Z	4.2	6.9	5.6
		Resultant	2.7	7.5	5.7
	HIC-36	Resultant	3.2	5.9	6.0
Head	Displacement (Front Camera)	Lateral	1.1	2.2	1.7
		Vertical	3.4	3.6	4.7
Upper Neck	Force	Y	1.2	4.4	3.7
		Z	3.7	7.6	5.7
	Moment	+X	1.2	3.0	3.9
		-X	1.2	0.7	1.6
Shoulder	Force	Y	1.3	3.2	2.7
T1	Acceleration	Y	1.4	4.8	3.6
		Resultant	1.3	4.8	3.5
T12	Acceleration	Y	0.4	1.2	2.5
		Resultant	0.4	1.1	2.8
Upper Rib	Displacement	Y	2.7	4.4	9.5
Middle Rib	Displacement	Y	3.3	5.9	4.5
Lower Rib	Displacement	Y	2.4	5.9	11.3
Abdomen-Front	Force	Y	1.6	4.9	9.5
Abdomen-Center	Force	Y	2.1	6.0	7.6
Abdomen-Rear	Force	Y	3.1	5.7	5.8
Abdomen-Sum	Force	Y	1.9	5.5	7.3
Lumbar	Force	Y	2.6	1.0	5.7
	Moment	+X	2.6	6.7	16.7
	Moment	-X	1.9	2.7	7.1
Pubic Symphysis	Force	Y	3.6	5.1	4.1
Pelvis	Acceleration	Y	2.1	2.7	4.2
		Resultant	0.6	2.4	3.2
Sled	Acceleration	X	0.2	0.2	0.1
Sled	Velocity	X	0.2	0.2	0.2

3.2.1 Sled Pulse Parameters

The peak sled acceleration and peak sled velocity provided extremely repeatable and reproducible test conditions with %CV values less than 0.5% for all tests. This was important to insure minimal test-to-test variations.

3.2.2 Head Responses

Similar to the flat wall test condition, the head acceleration responses were of low magnitude. With no head contact occurring during the event, the average HIC_{36} response for both dummies combined was only 53.3, an insignificant magnitude when compared to the proposed injury criteria of 1000. The repeatability for dummy 070 was below 5% (CV_{70}=3.2) while the repeatability of dummy 071 and the reproducibility of both dummies was slightly greater than 5% (CV_{71}=5.9; CV_{both}=6.0).

3.2.3 Spine Accelerations

The upper spine resultant acceleration (T1) responses exhibited excellent repeatability for each dummy and reproducibility for both dummies (CV_{70}=1.3; CV_{71}=4.8; CV_{both}=3.5).

The average responses of the lower spine resultant acceleration (T12) for both dummies was 92.8 g's, well over the proposed injury limit of 82 g's. This result provides a good indication of the severity of the loading that was imparted to this region of the dummy. The repeatability of the dummies' individual response was considered excellent (CV_{70}=0.4; CV_{71}=1.1), and the reproducibility of the responses was also well below 5% (CV_{both}=2.8).

3.2.4 Rib Displacements

In the abdomen offset tests, a much lower magnitude of rib displacement was observed than in the flat wall tests. With the protruding offset block oriented to impact directly with the abdomen, and with this impact occurring prior to any other contact, the abdomen absorbs much more of the load than it did in the flat wall tests. As a result, the rib displacements are quite low, while the abdominal loading is significantly higher. In any case, the rib displacement responses once again exhibit a smooth time-history with no indication of flat-topping.

Upper Rib Displacements

The repeatability of each dummy's response was below 5% (CV_{70}=2.7;CV_{71}=4.4). The reproducibility of both dummies was below 10% (CV_{both}=9.5).

Middle Rib Displacement

The repeatability of dummy 070's response and reproducibility for both dummies of the maximum middle rib displacement were less than 5% (CV_{70}=3.3; CV_{both}=4.5). The repeatability of dummy 071 was just above 5% (CV_{71}=5.9).

Lower Rib Displacement

The responses of the lower rib were slightly less repeatable and reproducible, however, this is partially attributed to the relatively small magnitude of the mean lower rib displacement, which was only 11.2 mm for both dummies, or less than a third of the proposed injury criteria. The repeatability of dummy 070's response was les than 5% (CV_{70}=2.4), the repeatability of dummy 071's response was just slightly above 5% (CV_{71}=5.9), while the reproducibility of both dummies' responses was greater than 10% (CV_{both}=11.3). Considering that the magnitude of the response was so small in relation to the proposed injury criteria, this result should not cause serious concern.

3.2.5 Abdominal Load

Given that the test condition was designed to directly impact the abdomen, it is not surprising that the abdomen loads observed were of such high magnitude. The average total abdominal load for all tests was 7070 N, or nearly three times the proposed injury criteria level of 2400 – 2800 N.

The repeatability of the maximum total abdominal load response for dummy 070 was less than 5% (CV_{70}=1.9) and the repeatability for dummy 071 was slightly greater than 5% (CV_{71}=5.5). The reproducibility of both dummies was less than 10% (CV_{both}=7.3).

3.2.6 Pubic Symphysis Load

For all tests, the peak pubic symphysis load was well below the proposed injury level of 6.0 kN. The repeatability of dummy 070 and the reproducibility of both dummies' maximum pubic symphysis loads were less than 5% (CV_{70}=3.6; CV_{both}=4.1). The repeatability of dummy 071 was only slightly greater than 5% (CV_{71}=5.1).

3.2.7 Other Responses

The dummy's head motion, as determined from the high-speed digital video analysis, exhibited highly consistent results. The peak lateral motion provided results which were extremely repeatable and reproducible (CV_{70}=1.1; CV_{71}=2.2; CV_{both}=1.7). Furthermore, the peak vertical displacement was also highly repeatable and reproducible (CV_{70}=3.4; CV_{71}=3.6; CV_{both}=4.7).

The reproducibility of the lateral lumbar bending moment response was greater than 10% (CV_{both}=16.7). While this result is considered poor, it should be noted that there was no apparent impact on the responses of the pelvis, abdomen, or thorax.

All other responses analyzed provided CV values less than 10% for both repeatability and reproducibility.

4 CONCLUSIONS

Two ES-2re dummies were exposed to two series of five Hyge sled tests, for a total of 10 test exposures per dummy. The two test conditions subjected the dummies to severe loading conditions. In the flat wall test condition, the dummies' rib displacement responses exceeded the proposed injury level, while in the abdomen offset test condition, the dummies' abdominal loads and resultant lower spine accelerations both exceeded the proposed criteria. The ES-2re dummies exhibited good durability by withstanding, without observable component damage or failure, the severe test conditions.

The R&R analysis indicates that the dummies were able to provide responses which were acceptable or better for nearly every proposed injury measure. The only injury measure that did not meet the acceptable criteria was the reproducibility of the lower rib displacement response in the abdomen offset tests. This measure resulted in a CV of 11.3%. Note, however, that in these tests the average lower rib displacement of 11.2 mm was substantially lower than the proposed injury level for this measurement (35-44 mm). Hence, this measure is determined to be borderline acceptable even though the CV exceeds 10%.

REFERENCES

Kuppa, S., “Injury Criteria for Side Impact Dummies”, May 2004, NHTSA docket #NHTSA-2004-17694.

APPENDIX A

Table A.1. Flat wall sled tests - Pre-test dummy seating measurement results

test # S0401---	07-1		07-2		08-1		08-2		08-3	
dummy S/N	070	071	070	071	070	071	070	071	070	071
first contact to wall (arm)	330	330	330	330	330	330	330	330	330	330
hip tool to wall	285	285	285	285	285	285	285	285	285	285
hip tool to front of seat	185	185	185	185	185	185	185	185	185	185
knee height	434	435	434	435	435	435	435	435	435	435
knee to wall	444	444	444	443	444	444	444	444	444	445
knee to knee	195	195	195	195	195	195	195	195	195	195
ankle to wall	465	465	465	464	465	465	465	465	463	465
ankle to ankle	260	260	260	260	260	260	260	260	260	260
shoulder to wall	403	401	401	403	402	401	402	401	400	402

Table A.2. Abdomen offset sled tests - Pre-test dummy seating measurement results

test # S0401---	07-1		07-2		08-1		08-2		08-3	
dummy S/N	070	071	070	071	070	071	070	071	070	071
first contact to wall (abdomen)	330	330	330	330	330	330	330	330	330	330
hip tool to wall	250	251	250	250	250	251	249	252	251	250
hip tool to front of seat	185	185	185	185	185	185	185	185	185	185
knee height	435	435	435	435	435	435	435	435	435	435
knee to wall	410	410	410	410	410	410	410	410	410	410
knee to knee	195	195	195	195	195	195	195	195	195	195
ankle to wall	429	429	429	429	429	429	429	429	429	429
ankle to ankle	260	260	260	260	260	260	260	260	260	260
shoulder to wall	360	360	360	359	361	362	363	363	364	364

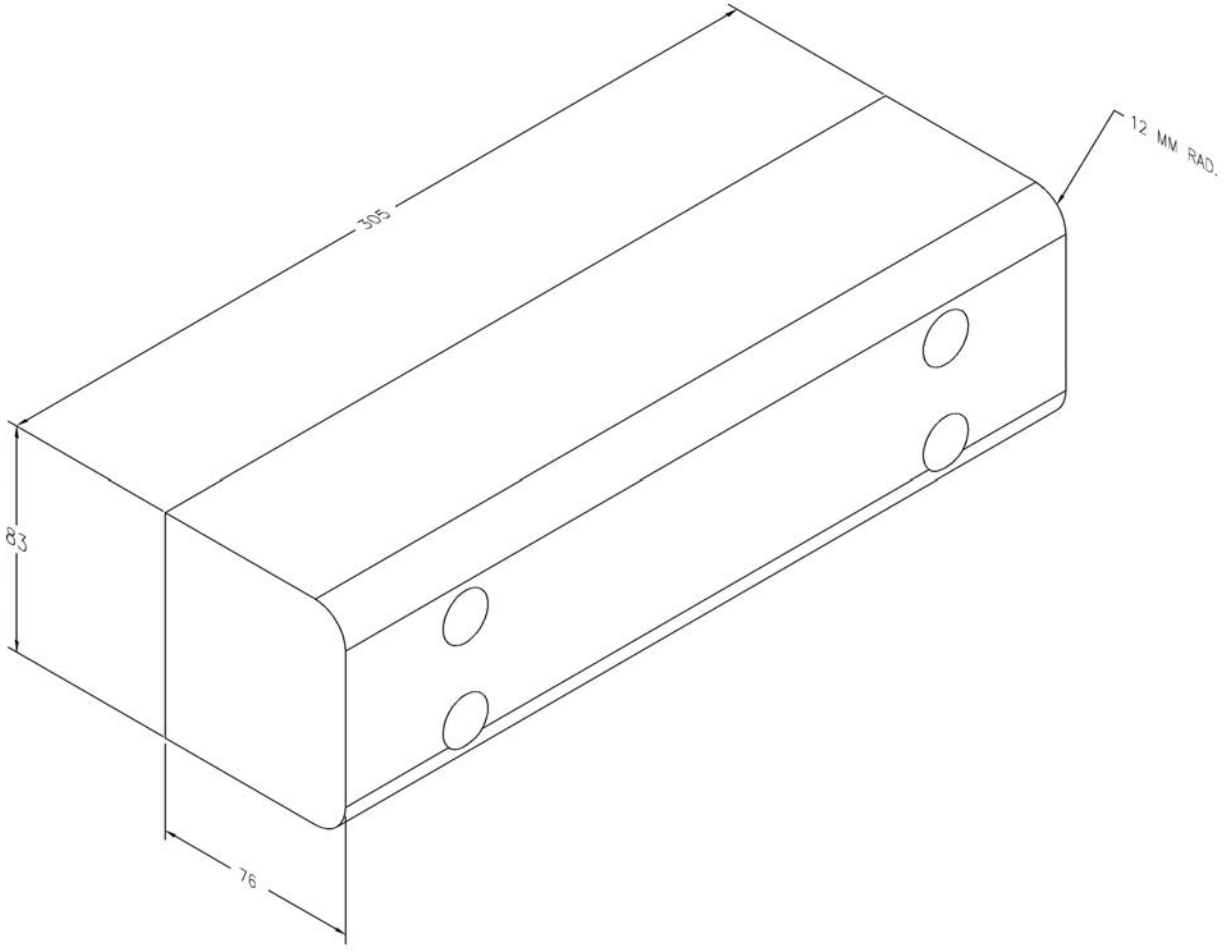

Figure A.1. Schematic of Abdomen Offset Block

APPENDIX B: 6.7 m/s Flat Wall Sled Test Responses

Table B.1. Summary of Peak Responses in 6.7 m/s Flat Wall Sled Tests

		Dummy SN		070					071				
		Dummy Location		Front	Front	Front	Front	Front	Rear	Rear	Rear	Rear	Rear
Location	**Measurement**	**Direction**	**Units**	S040107-1	S040107-2	S040108-1	S040108-2	S040108-3	S040107-1	S040107-2	S040108-1	S040108-2	S040108-3
Head CG	Acceleration	Y	g	15.3	15.7	14.9	15.1	16.5	12.9	13.9	13.6	13.2	13.4
		Z	g	21.9	21.7	22.1	21.6	21.6	22.9	22.6	23.4	23.7	23.5
		Resultant	g	22.8	22.4	22.8	22.6	23.0	25.2	25.2	26.0	26.2	25.9
	HIC	Resultant		52.6	50.9	49.1	50.3	52.3	50.7	52.4	52.4	53.2	55.4
Head	Displacement (Front Camera)	Lateral	mm	297.0	289.3	272.0	277.6	280.3	305.6	302.1	291.7	290.9	292.9
		Vertical	mm	-57.1	-54.7	-52.7	-56.3	-57.0	-61.6	-66.1	-58.4	-62.0	-60.8
		time	ms	57	54	53	53	56	56	57	56	54	55
Upper Neck	Force	Y	N	578.4	573.2	564.0	578.3	597.1	553.9	563.6	554.2	560.1	579.9
		Z	N	908.6	908.6	892.7	908.5	941.0	828.1	855.3	822.0	857.1	847.4
	Moment	+X	N-m	34.8	34.7	34.5	34.2	41.1	34.3	33.2	34.8	33.9	36.0
		-X	N-m	-37.6	-37.3	-34.0	-38.5	-42.4	-33.1	-34.2	-33.6	-33.8	-34.4
		-Y	N-m	-34.2	-33.7	-32.7	-32.2	-34.8	-31.1	-31.1	-35.1	-32.5	-34.6
		+Z	N-m	15.1	16.5	16.8	16.1	15.7	15.7	16.5	15.8	15.6	14.6
Shoulder	Force	Y	N	817.4	887.8	817.5	825.2	927.9	682.1	739.3	727.6	740.0	739.7
T1	Acceleration	Y	g	26.0	25.9	26.5	26.9	26.5	29.4	28.5	28.9	30.3	28.9
		Resultant	g	26.2	28.5	26.6	29.0	28.8	29.9	29.2	29.5	30.9	29.5
T12	Acceleration	Y	g	54.7	53.7	57.2	55.5	51.4	59.7	57.4	59.9	62.0	59.2
		Resultant	g	55.4	54.5	57.7	56.1	52.1	60.1	57.6	60.2	62.2	59.4
Upper Rib	Displacement	Y	mm	37.0	37.7	37.4	37.3	38.8	43.9	43.2	45.4	44.4	45.5
Middle Rib	Displacement	Y	mm	42.0	42.6	42.3	41.9	42.0	45.5	45.7	46.7	46.5	46.8
Lower Rib	Displacement	Y	mm	39.4	39.9	39.8	39.4	39.1	41.4	40.8	41.5	41.3	41.9
Abdomen-Front	Force	Y	N	341.7	341.0	377.8	406.0	348.0	337.7	317.4	342.1	361.4	345.1
Abdomen-Center	Force	Y	N	595.0	607.9	666.5	618.9	542.0	628.5	596.2	638.4	681.2	647.9
Abdomen-Rear	Force	Y	N	451.4	473.7	506.7	446.1	423.4	546.4	496.5	537.7	561.1	521.7
Abdomen-Sum *	Force	Y	N	1375.0	1404.3	1528.9	1450.2	1302.9	1504.8	1402.3	1506.2	1592.1	1510.1
Lumbar	Force	Y	N	541.3	582.0	721.1	621.8	490.6	817.6	670.0	826.2	808.0	687.5
	Moment	+X	N-m	61.7	62.0	65.1	59.7	60.9	64.8	67.8	66.4	65.3	65.5
Pubic Symphysis	Force	Y	N	-3288.2	-3552.3	-3634.8	-3390.4	-3361.7	-3264.5	-3060.9	-3335.3	-3293.5	-3285.5
Pelvis	Acceleration	Y	g	74.2	85.2	87.9	90.2	82.8	79.6	80.3	88.3	86.1	86.9
		Resultant	g	83.2	85.3	87.9	90.7	83.2	79.8	80.7	88.4	86.4	87.4
Sled	Acceleration	X	g	-12.55	-12.65	-12.62	-12.61	-12.67	-12.55	-12.65	-12.62	-12.61	-12.67
Sled	Velocity	X	m/s	-6.72	-6.75	-6.74	-6.74	-6.75	-6.72	-6.75	-6.74	-6.74	-6.75

Table B.2. Statistical Analysis for 6.7 m/s Flat Wall Sled Tests

			Dummy SN	070			071			070 & 071		
			Dummy Location	Front			Rear			Front & Rear		
Location	**Measurement**	**Direction**	**Units**	AVG	SD	%CV	AVG	SD	%CV	AVG	SD	% CV
Head CG	Acceleration	Y	g	15.5	0.7	4.2	13.4	0.4	3.0	14.5	1.2	8.4
		Z	g	21.8	0.2	1.0	23.2	0.4	1.9	22.5	0.8	3.6
		Resultant	g	22.7	0.2	1.0	25.7	0.5	1.9	24.2	1.6	6.7
	HIC	Resultant		51.0	1.4	2.8	52.8	1.7	3.2	51.9	1.8	3.4
Head	Displacement (Front Camera)	Lateral	mm	283.2	9.9	3.5	296.6	6.7	2.3	289.9	10.7	3.7
		Vertical	mm	-55.6	1.9	3.4	-61.8	2.8	4.5	-58.7	4.0	6.8
		time	ms	54.6	1.8	3.3	55.6	1.1	2.1	55.1	1.5	2.8
Upper Neck	Force	Y	N	578.2	12.1	2.1	562.3	10.6	1.9	570.3	13.6	2.4
		Z	N	911.9	17.7	1.9	842.0	16.1	1.9	876.9	40.1	4.6
	Moment	+X	N-m	35.8	2.9	8.2	34.4	1.0	3.0	35.1	2.2	6.3
		-X	N-m	-38.0	3.0	7.9	-33.8	0.5	1.5	-35.9	3.0	8.3
		-Y	N-m	-33.5	1.1	3.3	-32.9	1.9	5.7	-33.2	1.5	4.5
		+Z	N-m	16.0	0.7	4.2	15.7	0.7	4.3	15.9	0.7	4.2
Shoulder	Force	Y	N	855.2	50.2	5.9	725.7	25.0	3.4	790.4	77.8	9.8
T1	Acceleration	Y	g	26.4	0.4	1.5	29.2	0.7	2.4	27.8	1.6	5.7
		Resultant	g	27.8	1.3	4.8	29.8	0.7	2.2	28.8	1.4	5.0
T12	Acceleration	Y	g	54.5	2.2	4.0	59.6	1.7	2.8	57.1	3.3	5.7
		Resultant	g	55.1	2.1	3.8	59.9	1.6	2.8	57.5	3.1	5.3
Upper Rib	Displacement	Y	mm	37.7	0.7	1.9	44.5	1.0	2.2	41.1	3.7	9.0
Middle Rib	Displacement	Y	mm	42.1	0.3	0.7	46.2	0.6	1.3	44.2	2.2	5.0
Lower Rib	Displacement	Y	mm	39.5	0.3	0.9	41.4	0.4	0.9	40.5	1.1	2.6
Abdomen-Front	Force	Y	N	362.9	28.4	7.8	340.7	15.8	4.6	351.8	24.6	7.0
Abdomen-Center	Force	Y	N	606.1	44.9	7.4	638.4	30.8	4.8	622.2	40.1	6.4
Abdomen-Rear	Force	Y	N	460.3	31.5	6.9	532.7	24.8	4.6	496.5	46.6	9.4
Abdomen-Sum *	Force	Y	N	1412.2	84.3	6.0	1503.1	67.4	4.5	1457.7	86.4	5.9
Lumbar	Force	Y	N	591.3	87.3	14.8	761.8	76.4	10.0	676.6	118.6	17.5
	Moment	+X	N-m	61.9	2.0	3.2	66.0	1.2	1.8	63.9	2.7	4.1
Pubic Symphysis	Force	Y	N	-3445.5	143.2	4.2	-3247.9	107.7	3.3	-3346.7	158.5	4.7
Pelvis	Acceleration	Y	g	84.1	6.2	7.3	84.3	4.0	4.8	84.2	4.9	5.8
		Resultant	g	86.1	3.2	3.8	84.6	4.0	4.7	85.3	3.5	4.1
Sled	Acceleration	X	g	-12.62	0.05	0.4	-12.62	0.05	0.4	-12.62	0.04	0.3
Sled	Velocity	X	m/s	-6.74	0.01	0.2	-6.74	0.01	0.2	-6.74	0.01	0.2

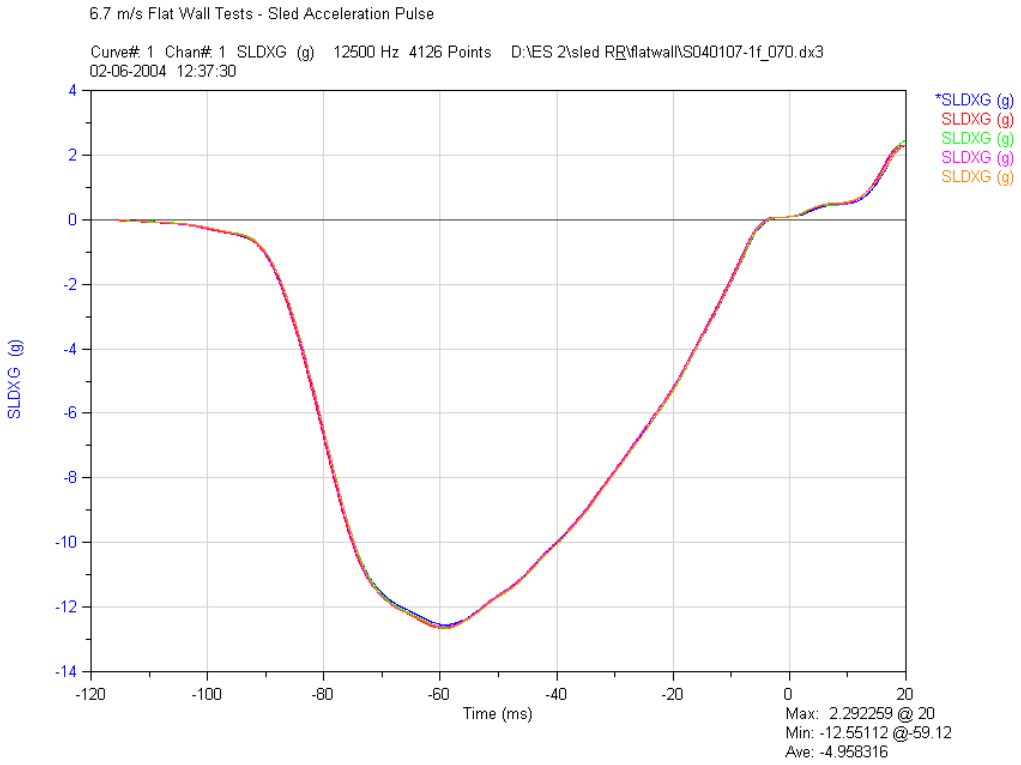

Figure B.1. Sled Acceleration Pulse

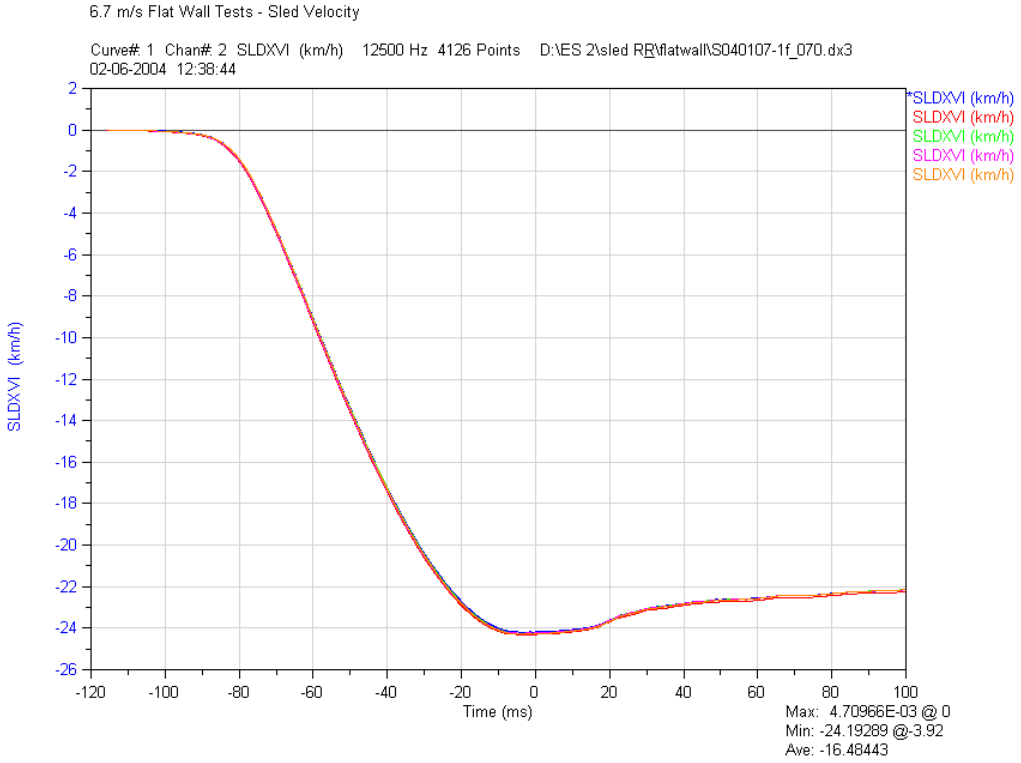

Figure B.2. Sled Velocity

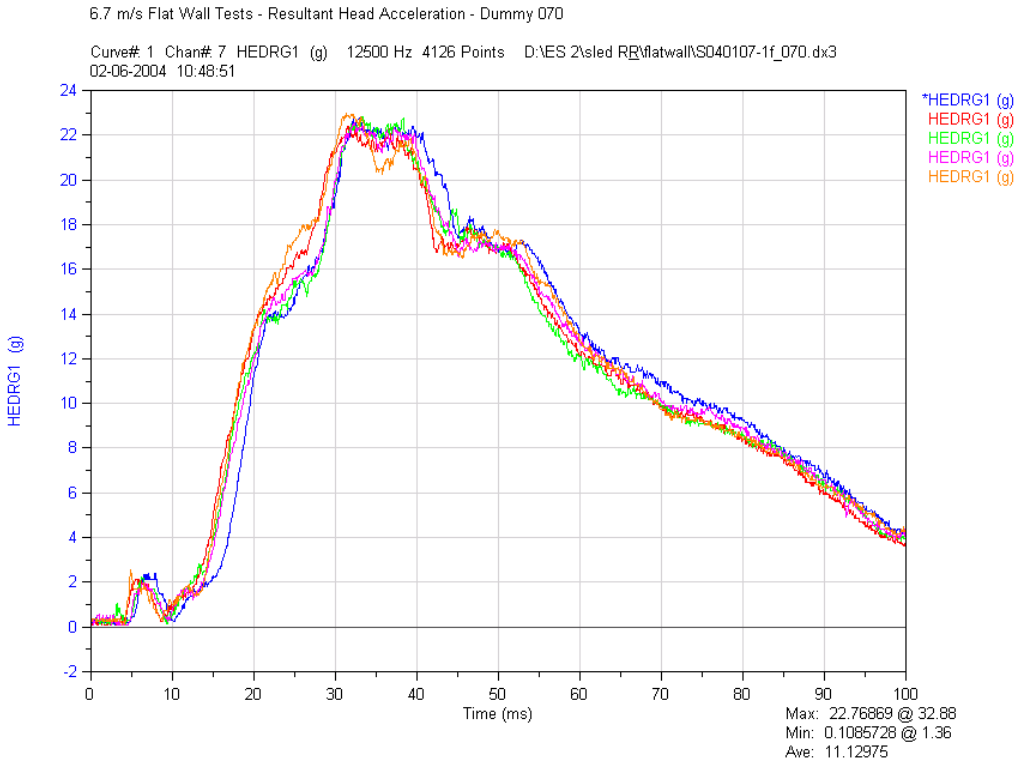

Fig. B.3.a. Resultant Head Acceleration – Dummy 070

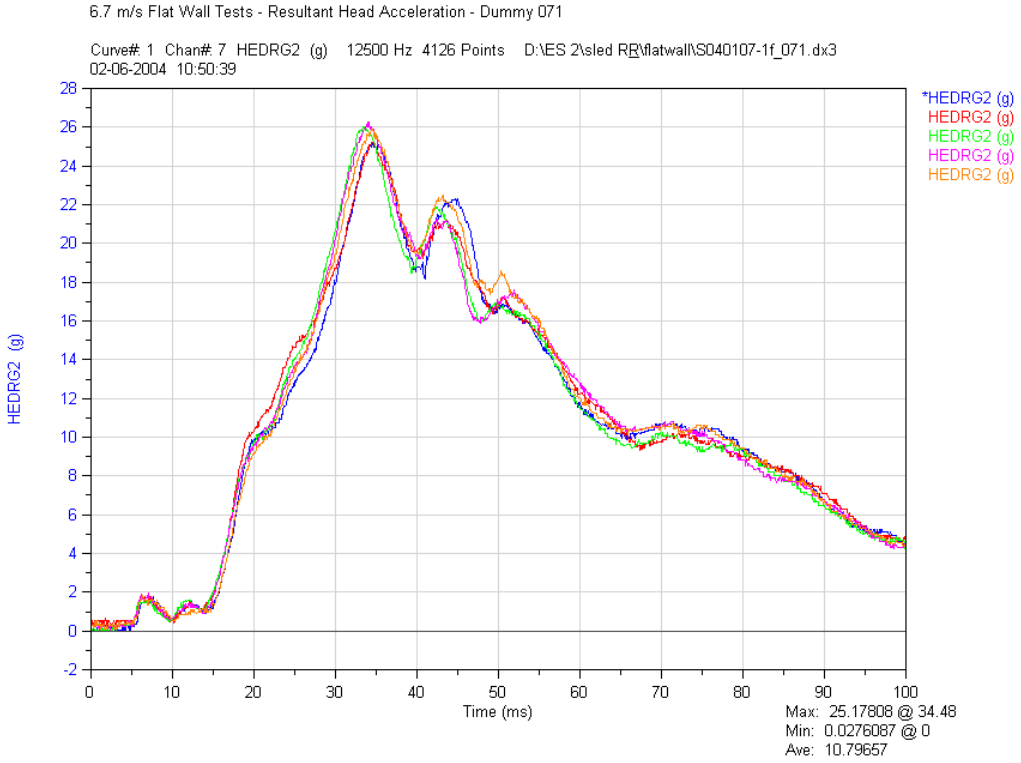

Fig. B.3.b. Resultant Head Acceleration – Dummy 071

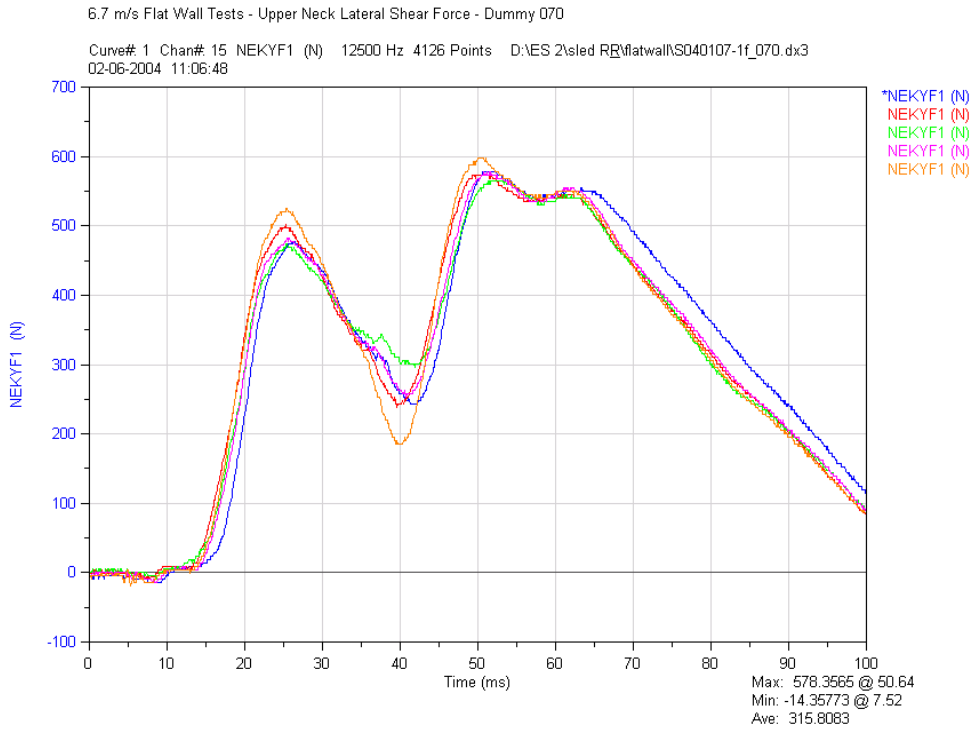

Figure B.4.a. Upper Neck Lateral Shear Force – Dummy 070

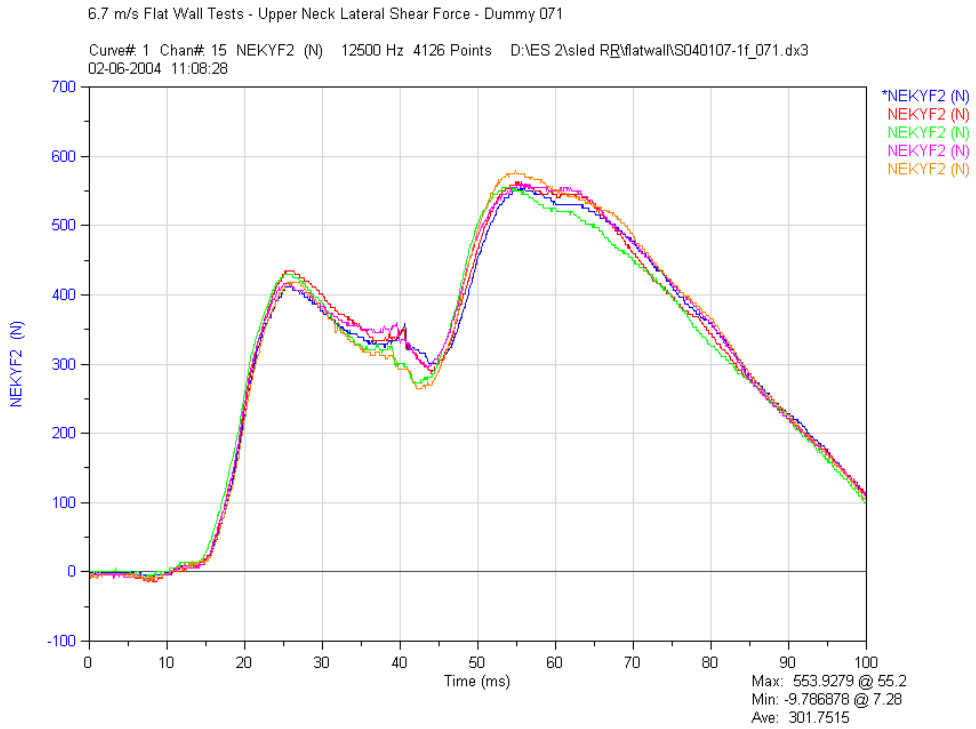

Figure B.4.b. Upper Neck Lateral Shear Force – Dummy 071

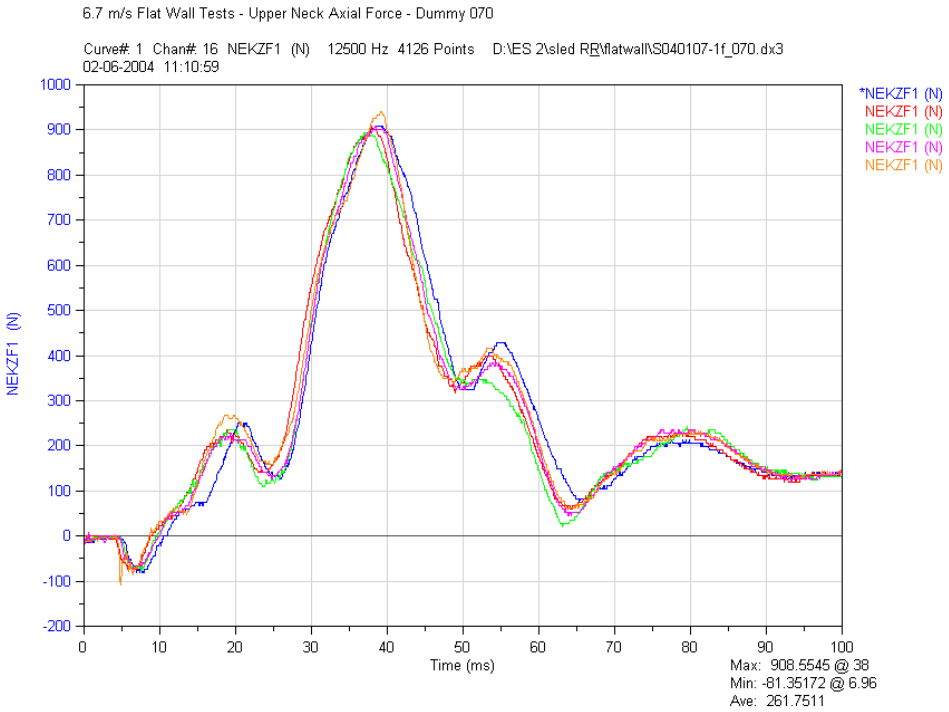

Figure B.5.a. Upper Neck Axial Force – Dummy 070

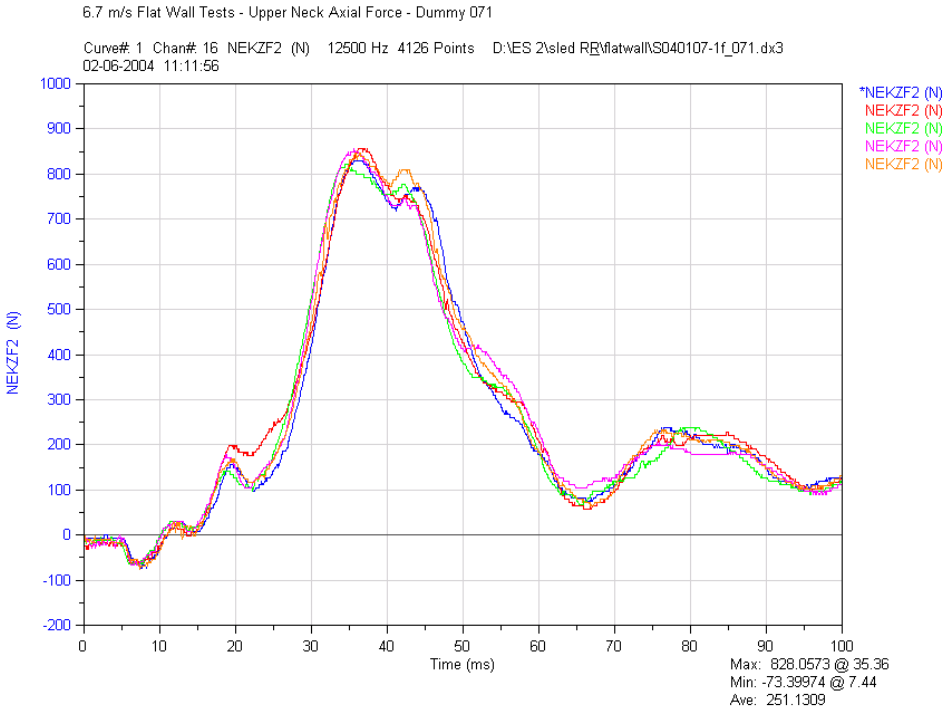

Figure B.5.b. Upper Neck Axial Force – Dummy 071

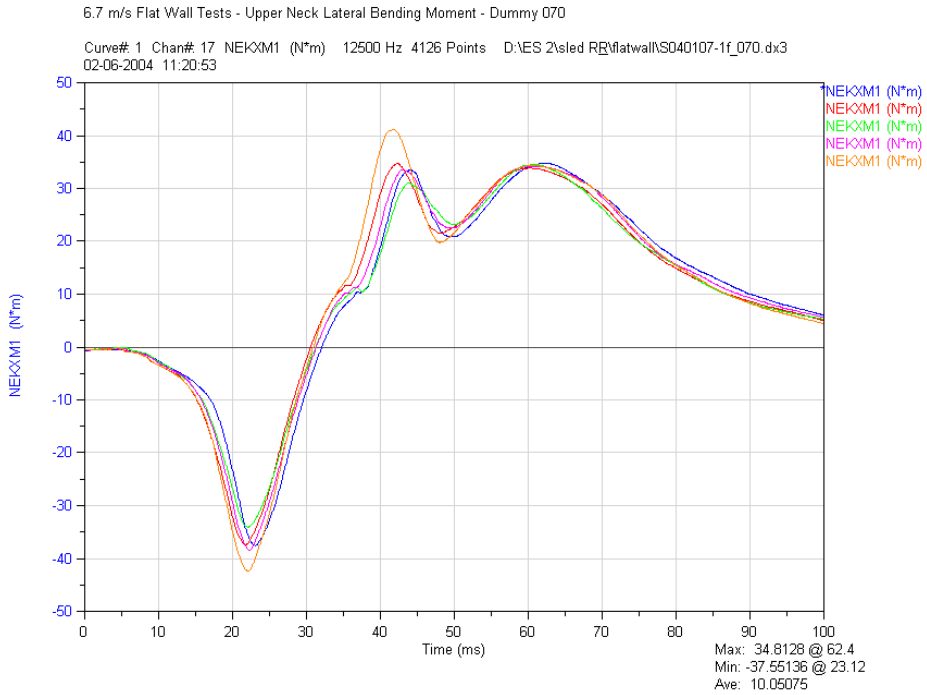

Figure B.6.a. Upper Neck Lateral Bending Moment – Dummy 070

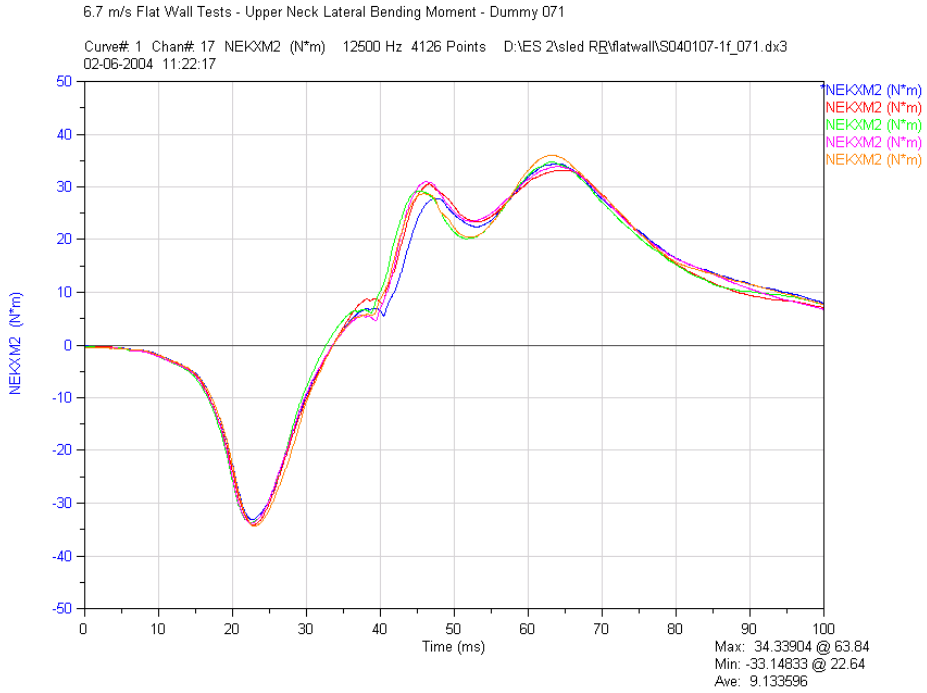

Figure B.6.b. Upper Neck Lateral Bending Moment – Dummy 071

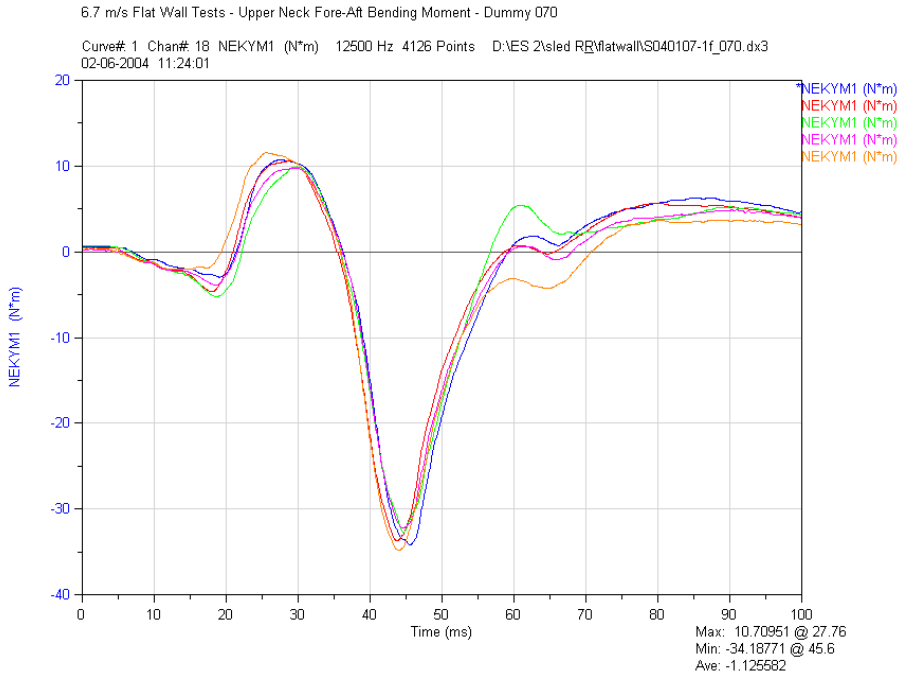

Figure B.7.a. Upper Neck Fore/Aft Moment – Dummy 070

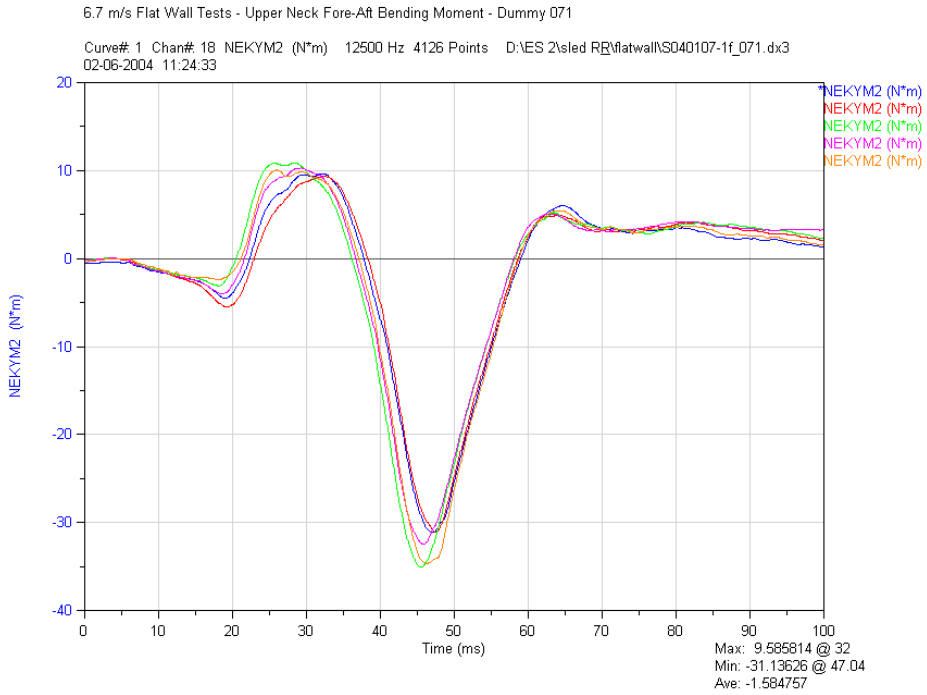

Figure B.7.b. Upper Neck Fore/Aft Moment – Dummy 071

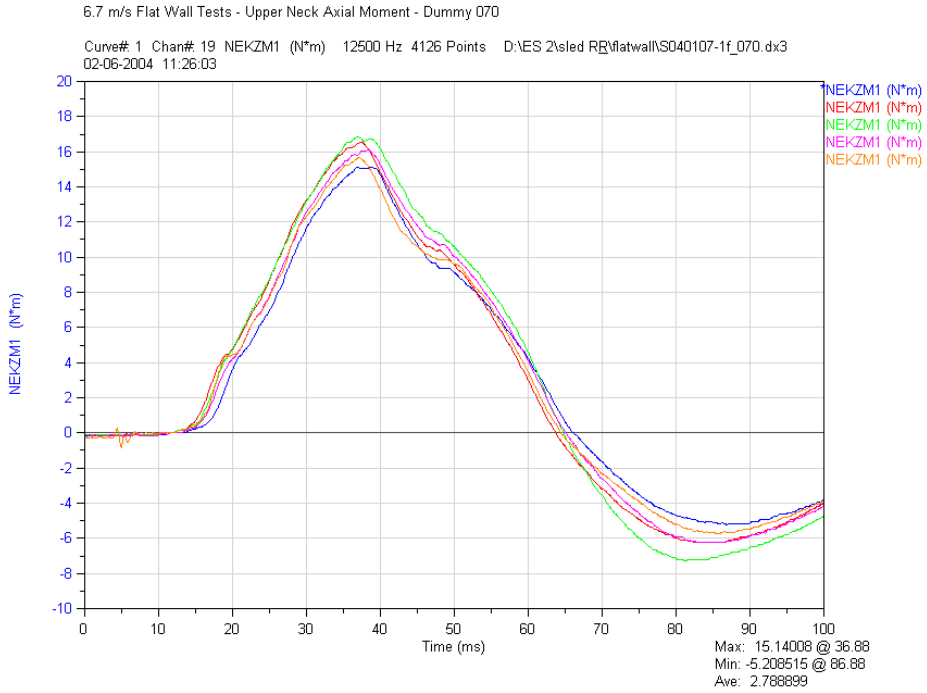

Figure B.8.a. Upper Neck Axial Moment – Dummy 070

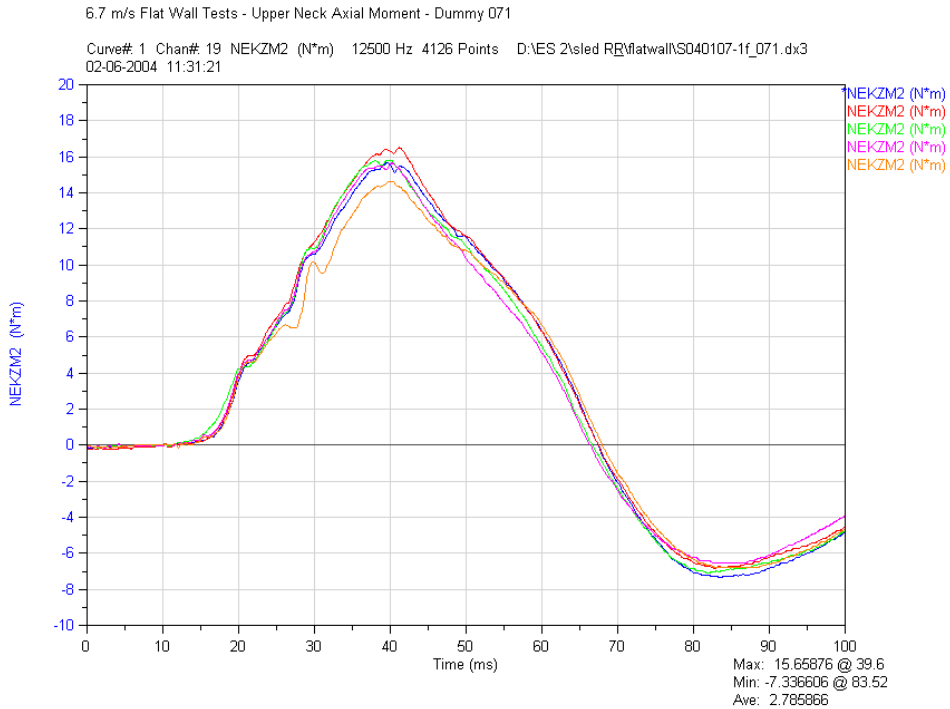

Figure B.8.b. Upper Neck Axial Moment – Dummy 071

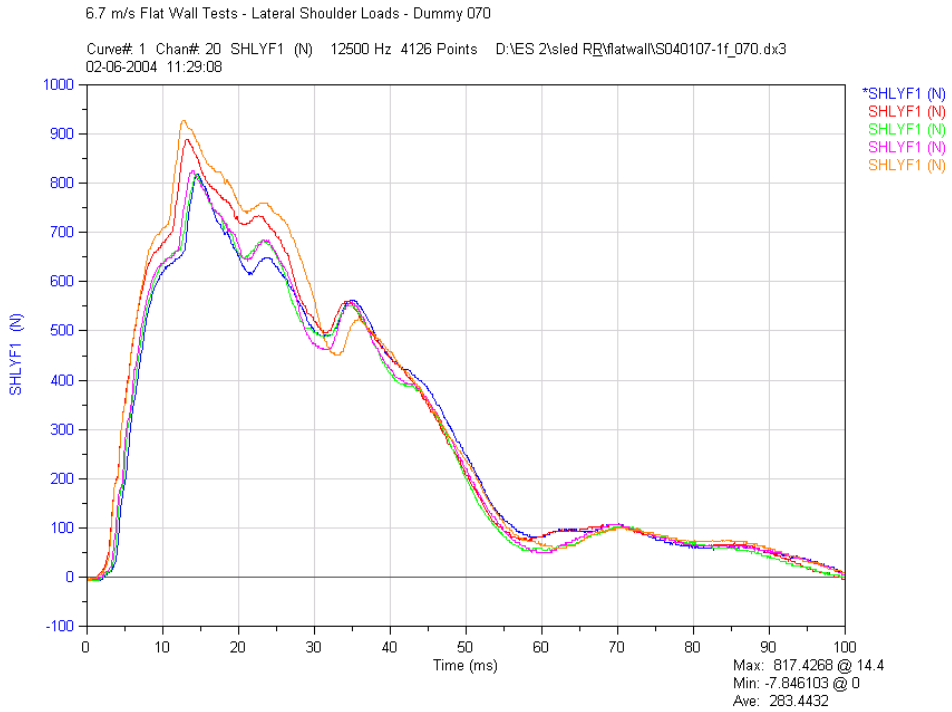

Figure B.9.a. Lateral Shoulder Loads – Dummy 070

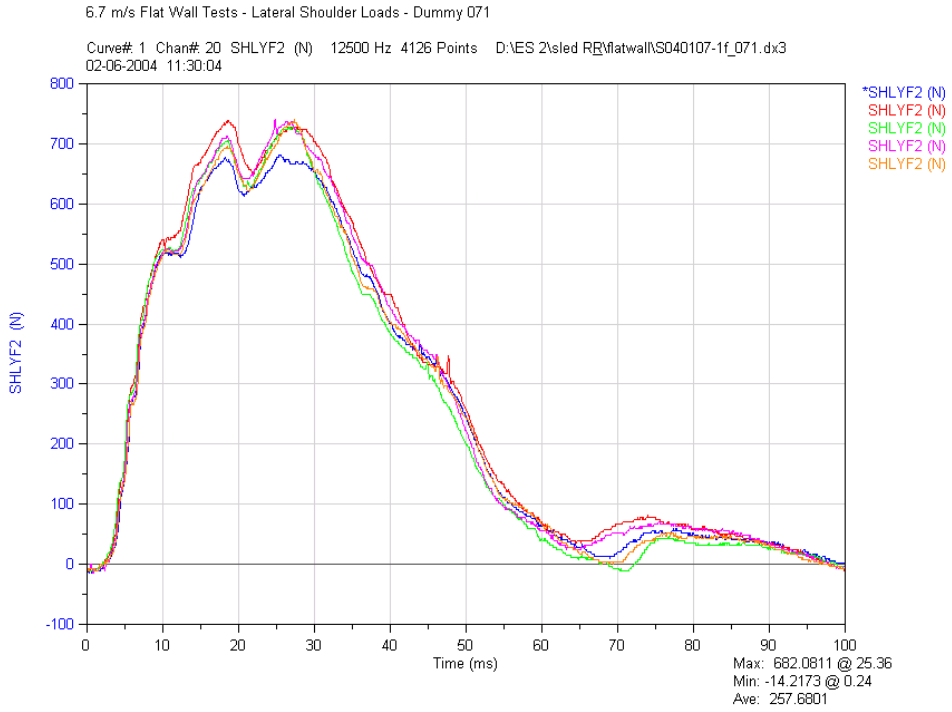

Figure B.9.b. Lateral Shoulder Loads – Dummy 071

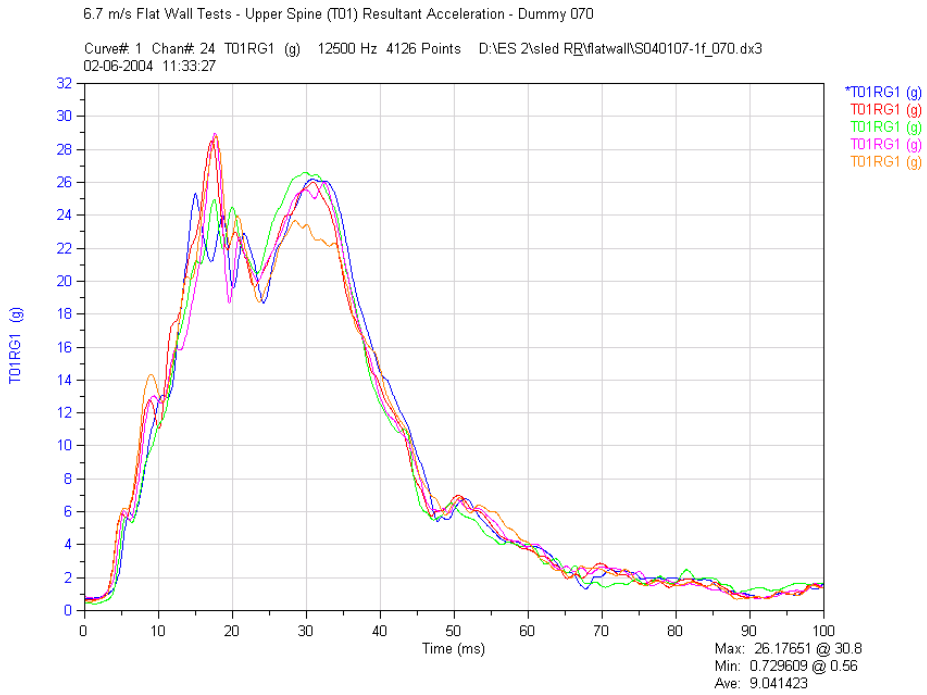

Figure B.10.a. Upper Spine Resultant Acceleration – Dummy 070

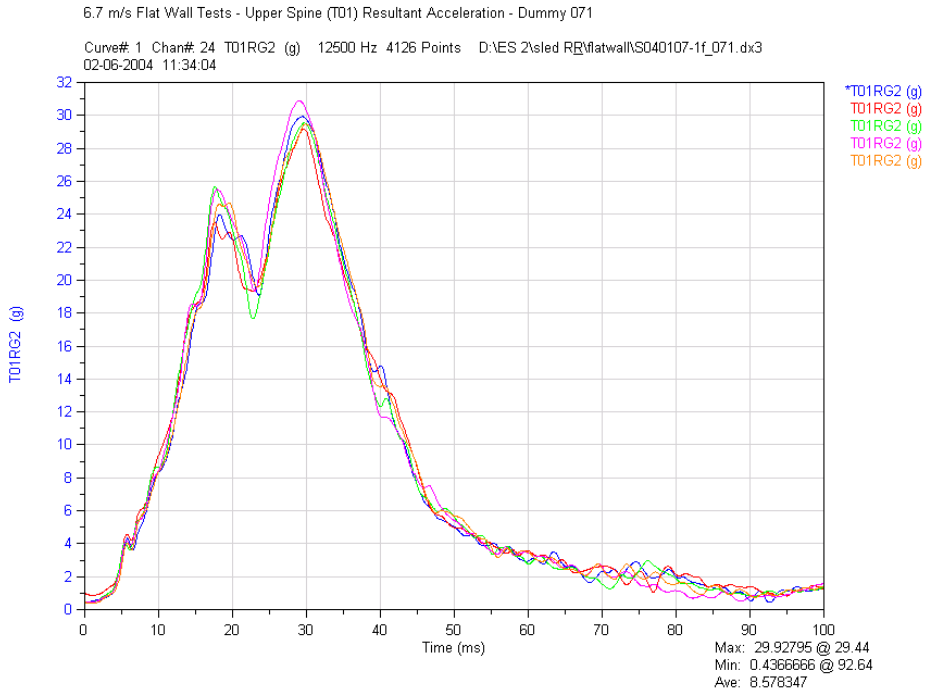

Figure B.10.b. Upper Spine Resultant Acceleration – Dummy 071

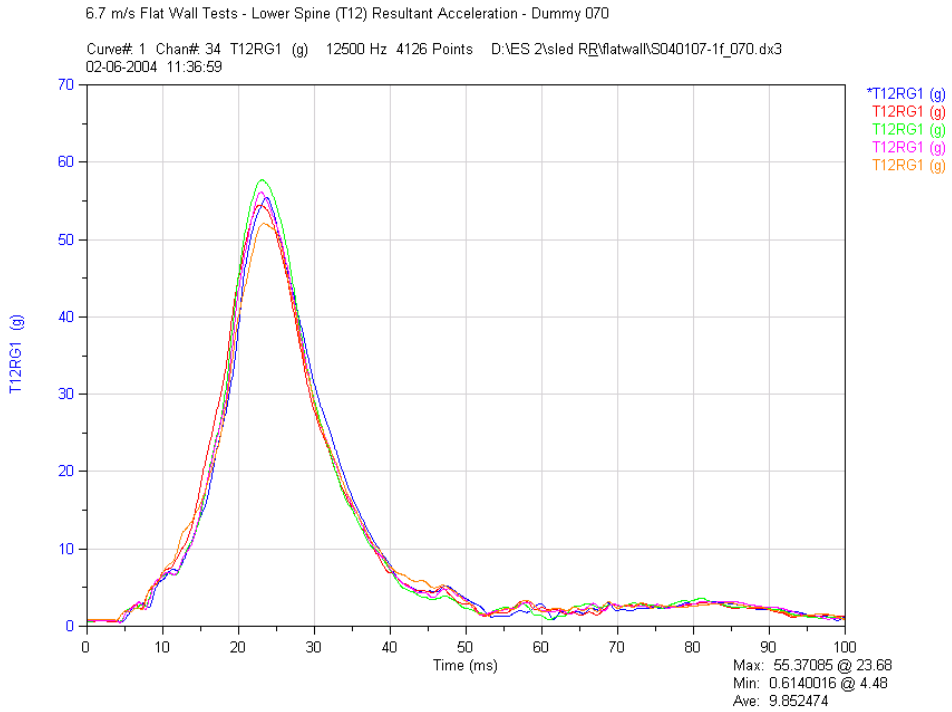

Figure B.11.a. Lower Spine Resultant Acceleration – Dummy 070

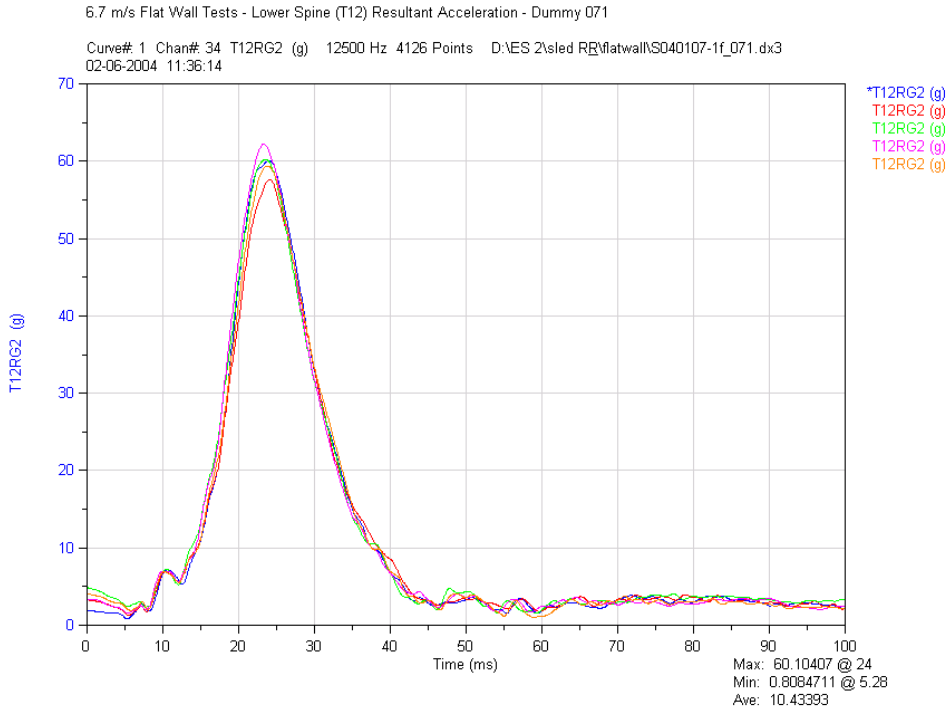

Figure B.11.b. Lower Spine Resultant Acceleration – Dummy 071

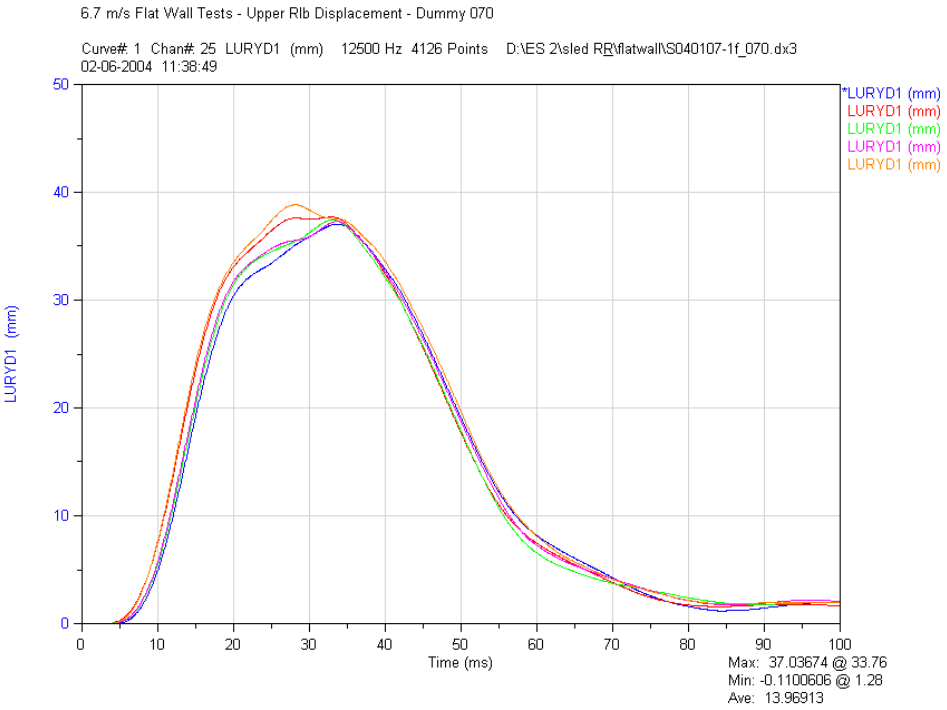

Figure B.12.a. Upper Rib Displacement – Dummy 070

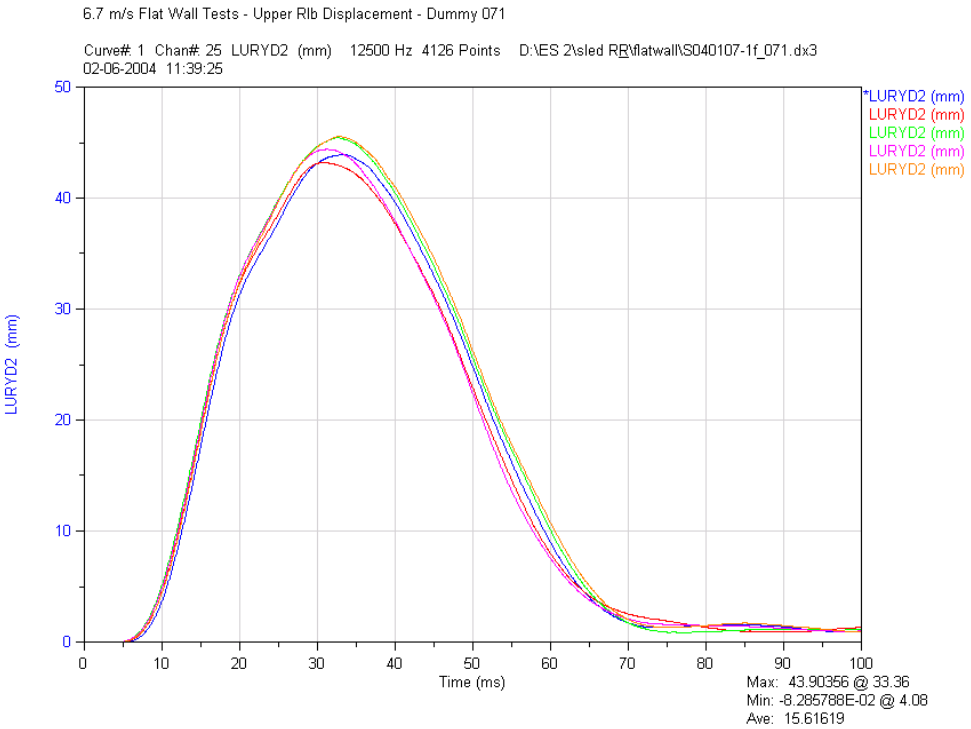

Figure B.12.b. Upper Rib Displacement – Dummy 071

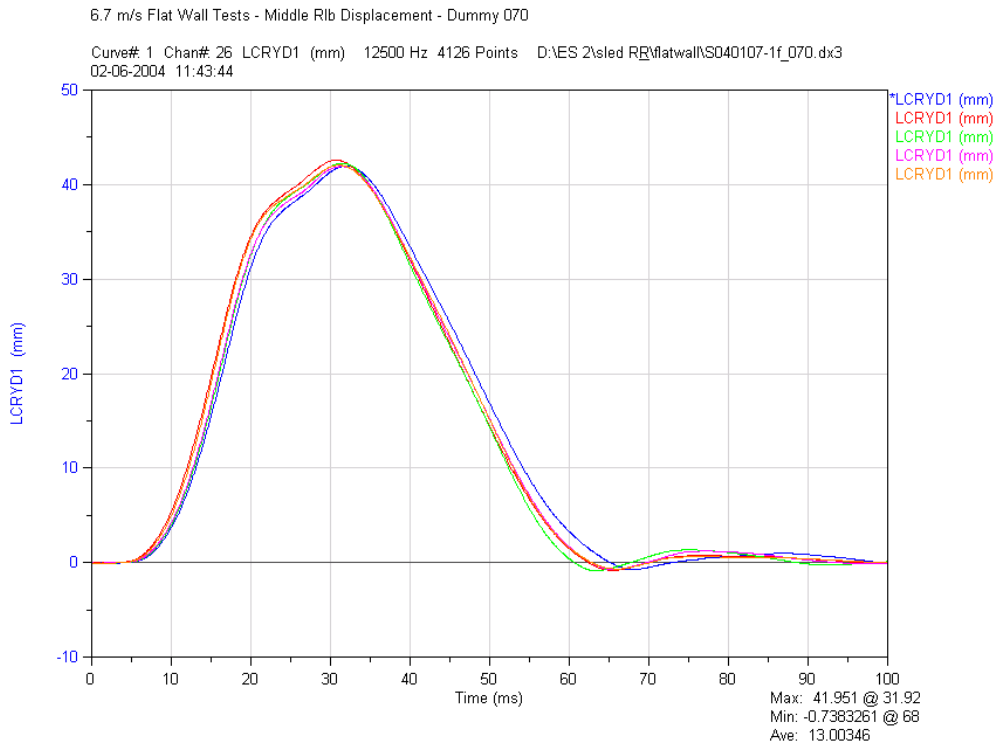

Figure B.13.a. Middle Rib Displacement – Dummy 070

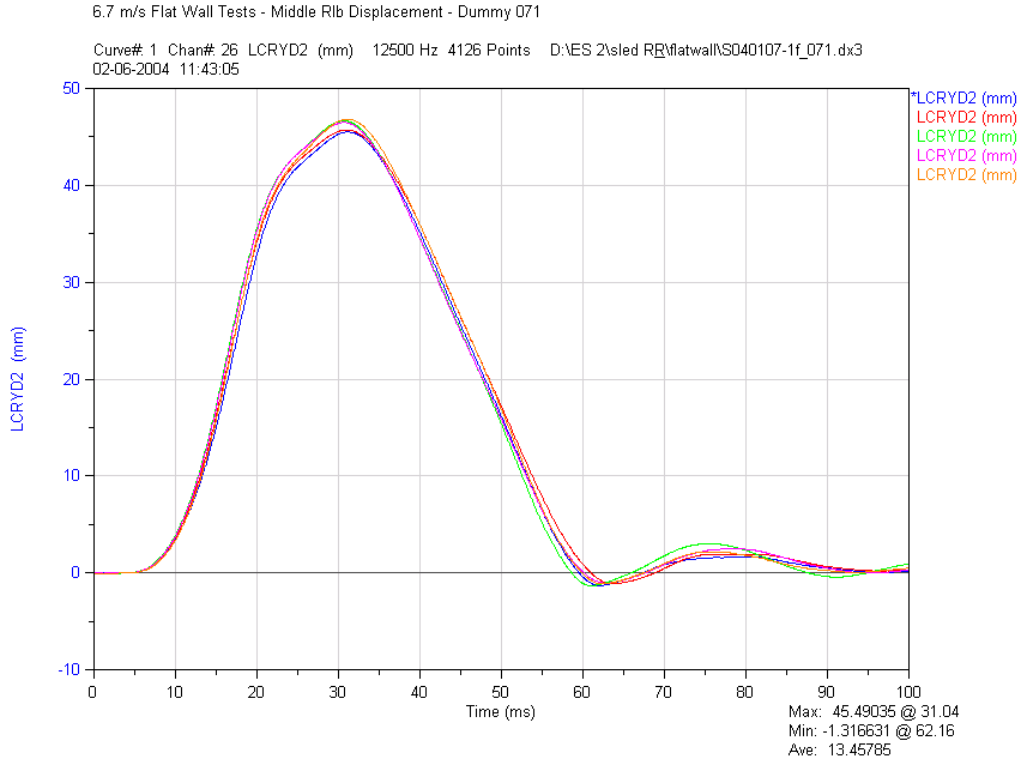

Figure B.13.b. Middle Rib Displacement – Dummy 071

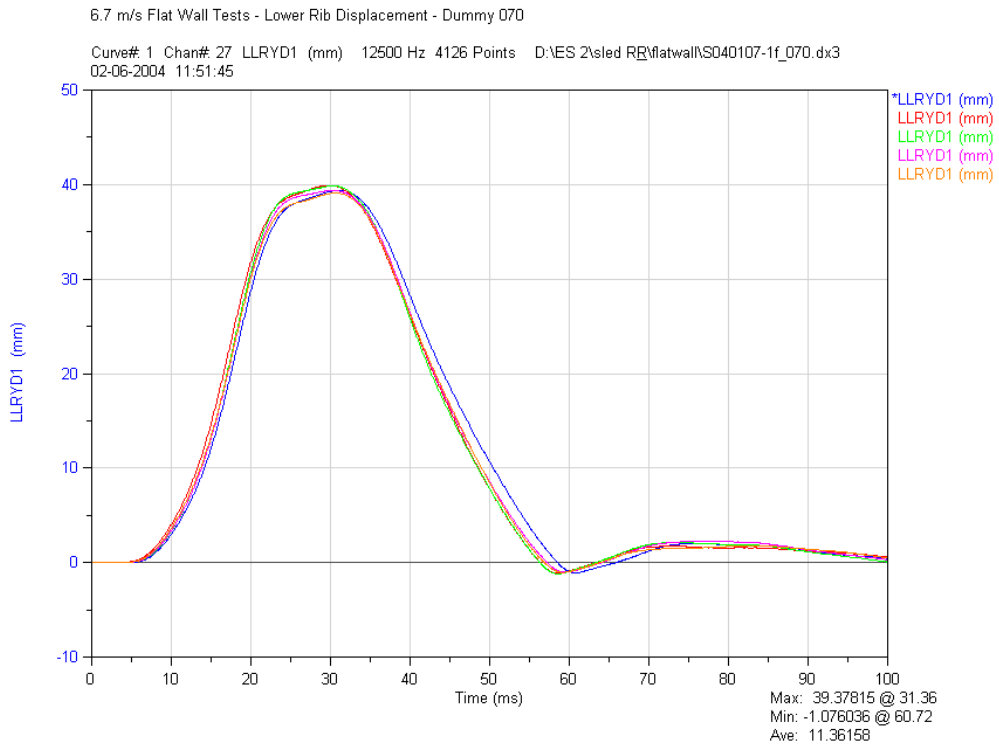

Figure B.14.a. Lower Rib Displacement – Dummy 070

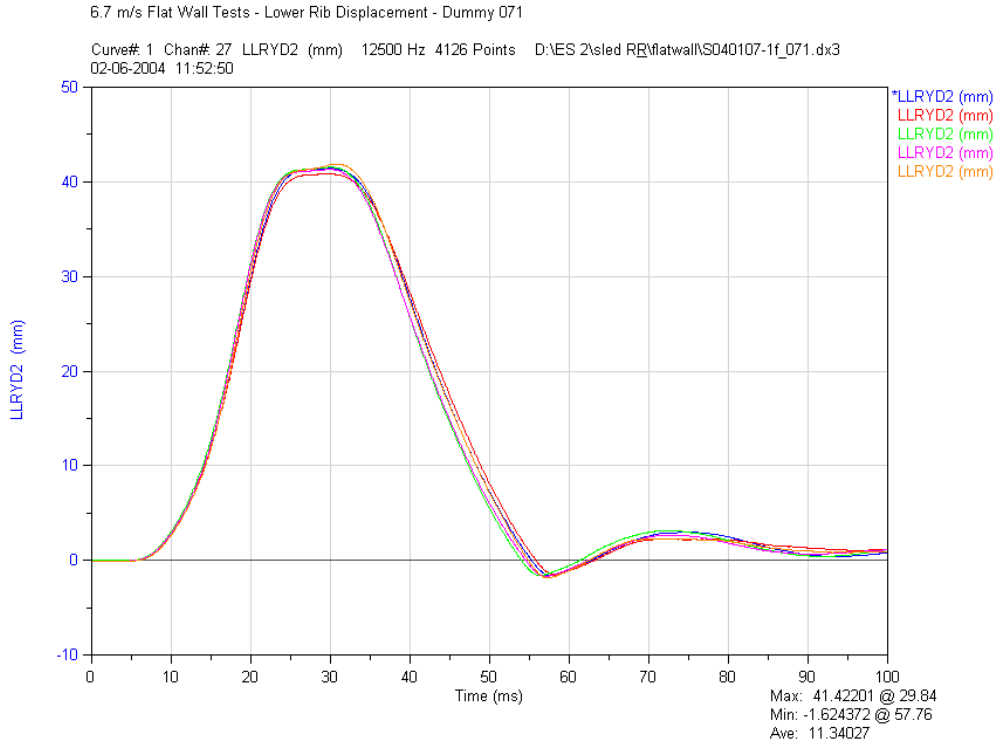

Figure B.14.b. Lower Rib Displacement – Dummy 071

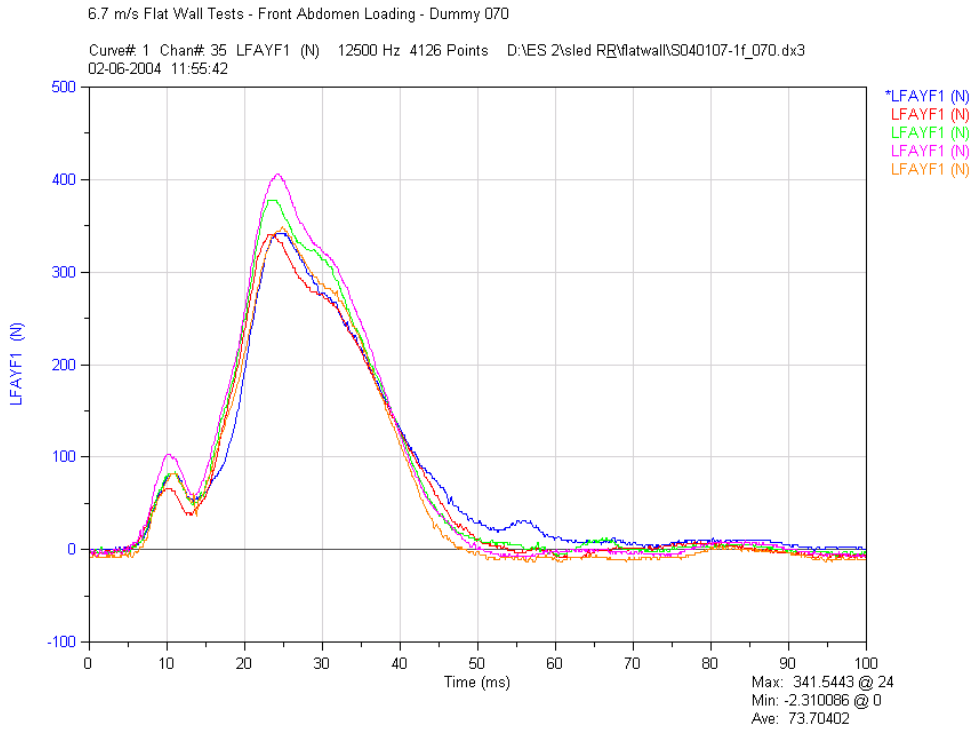

Figure B.15.a. Front Abdomen Loading – Dummy 070

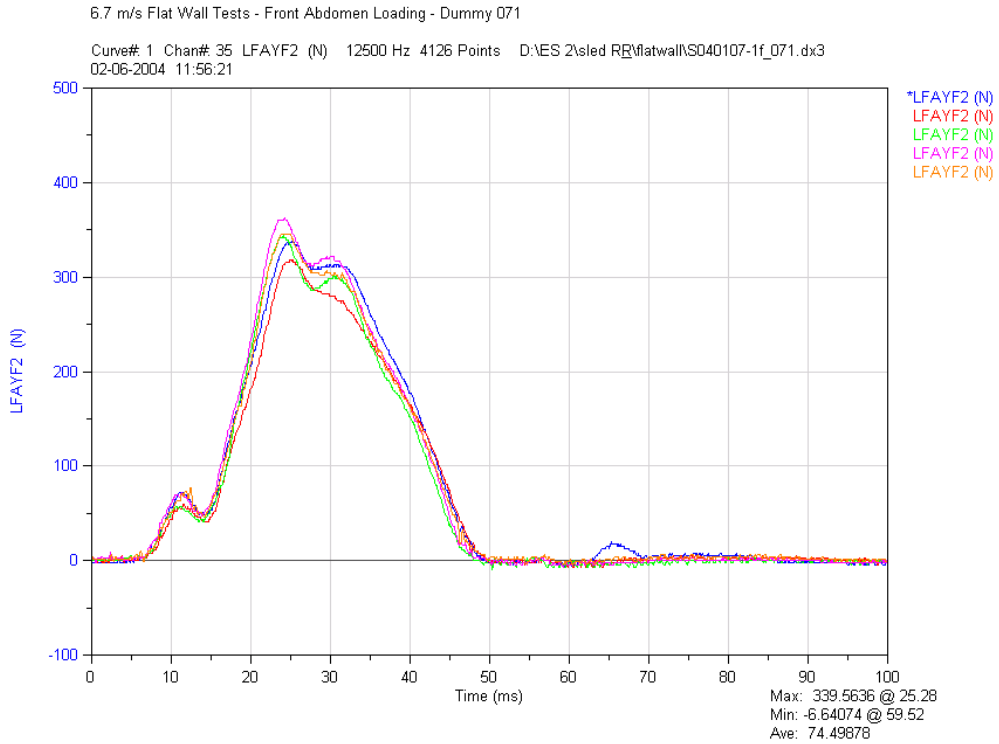

Figure B.15.b. Front Abdomen Loading – Dummy 071

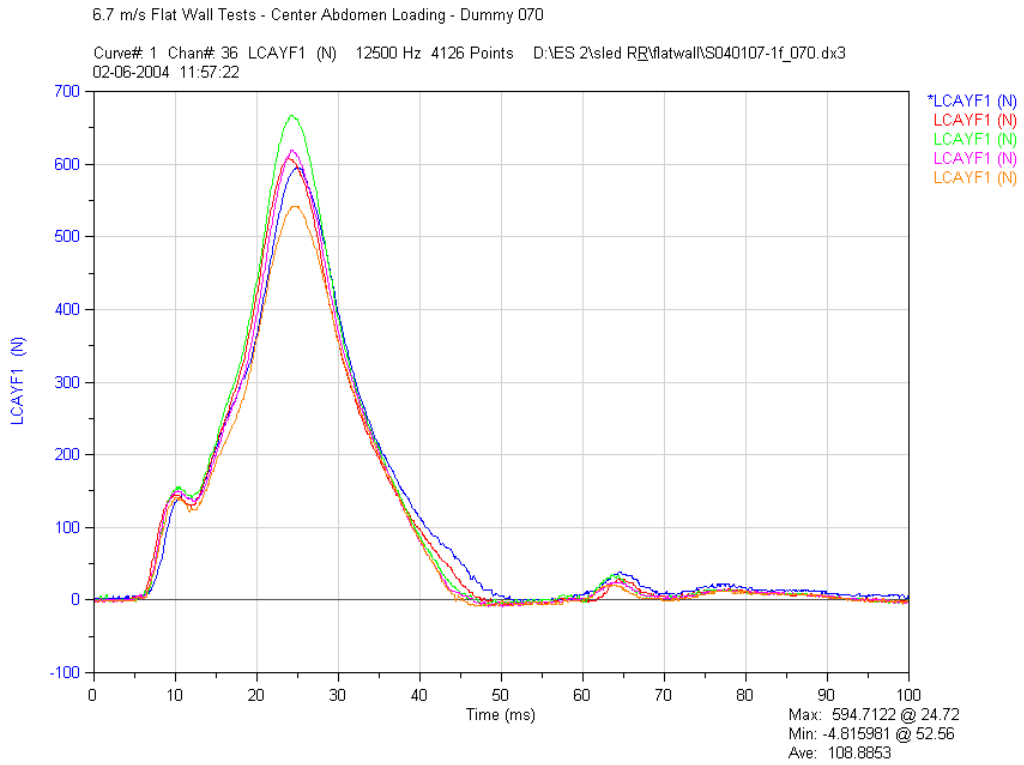

Figure B.16.a. Center Abdomen Loading – Dummy 070

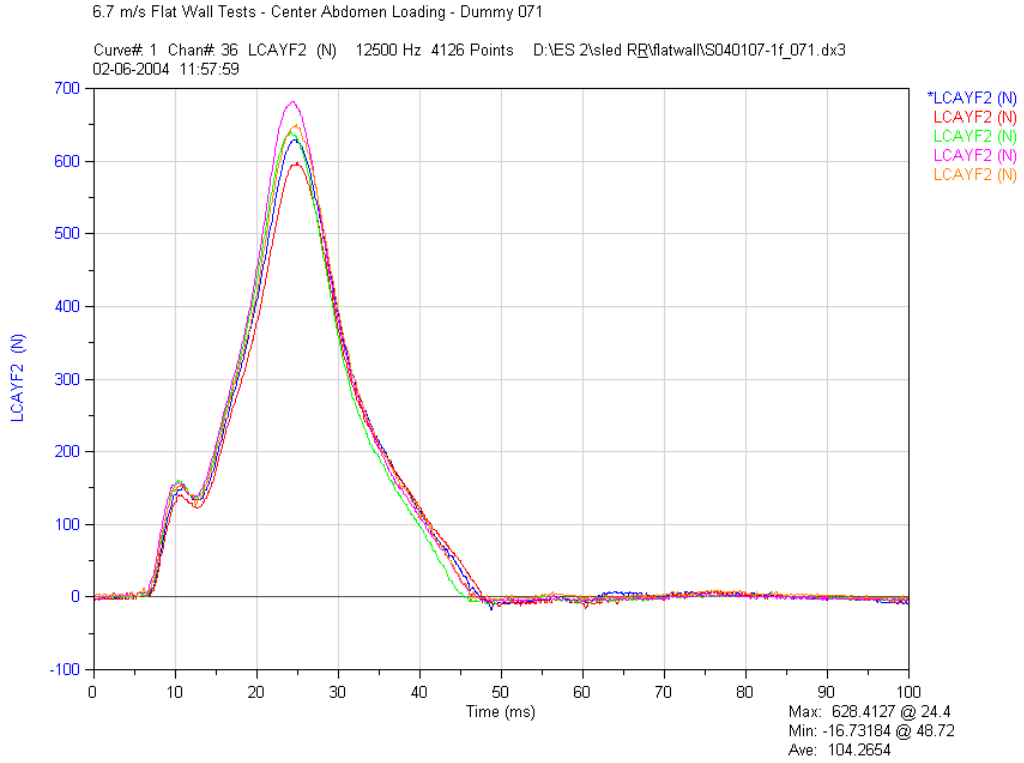

Figure B.16.b. Center Abdomen Loading – Dummy 071

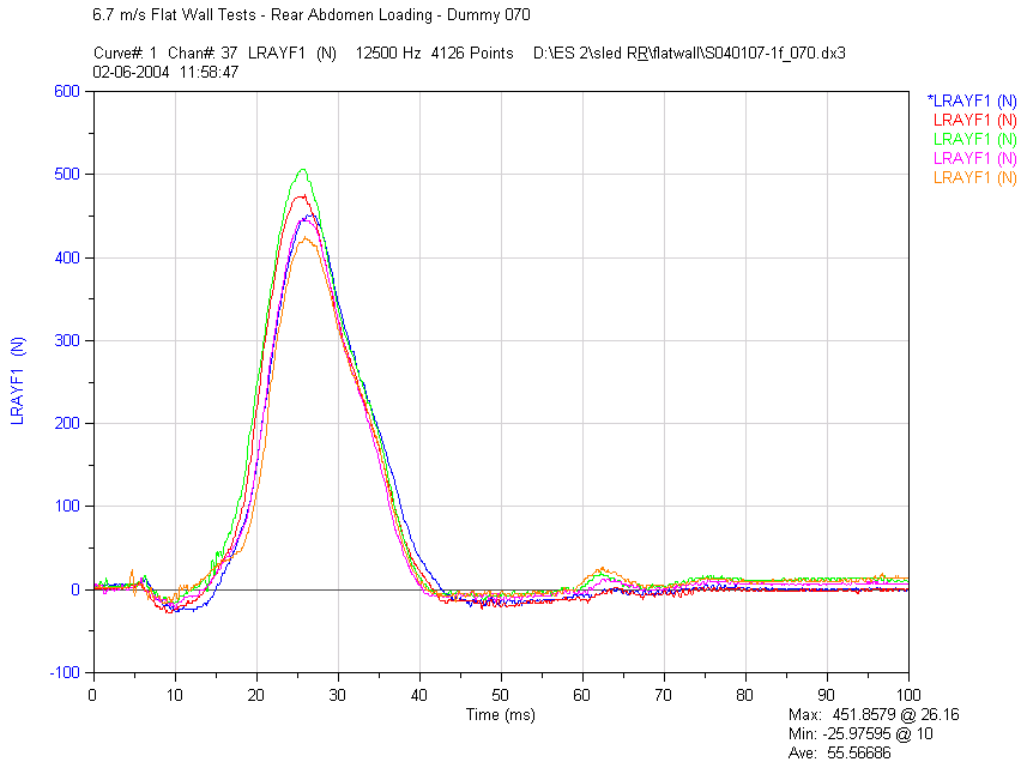

Figure B.17.a. Rear Abdomen Loading – Dummy 070

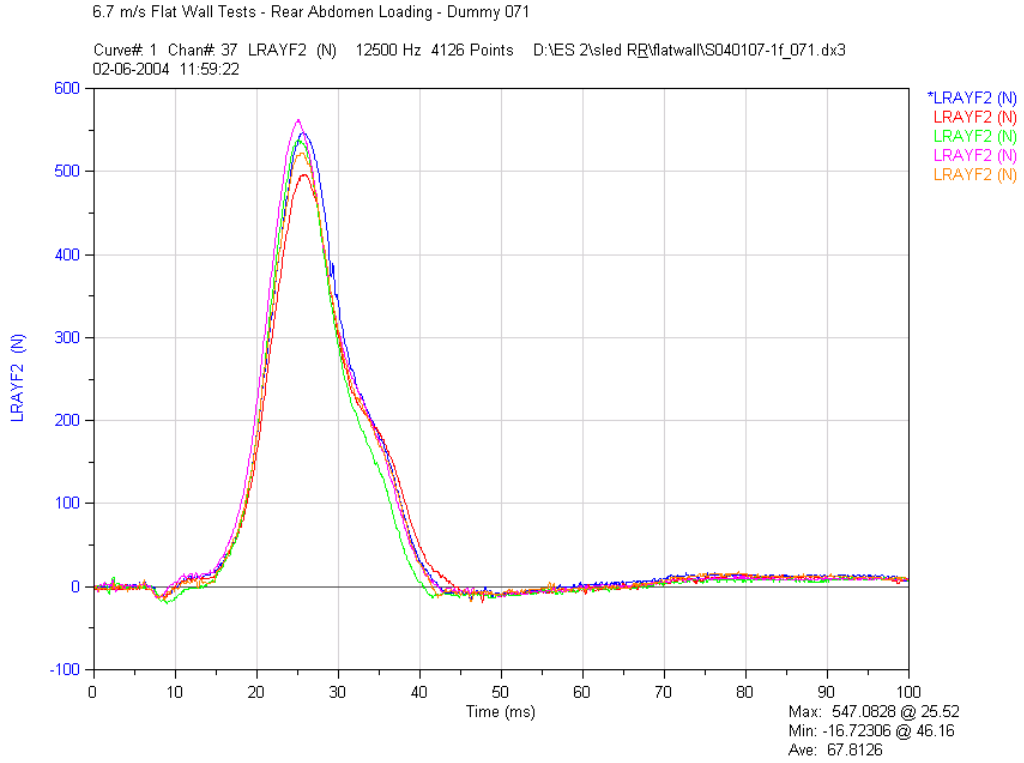

Figure B.17.b. Rear Abdomen Loading – Dummy 071

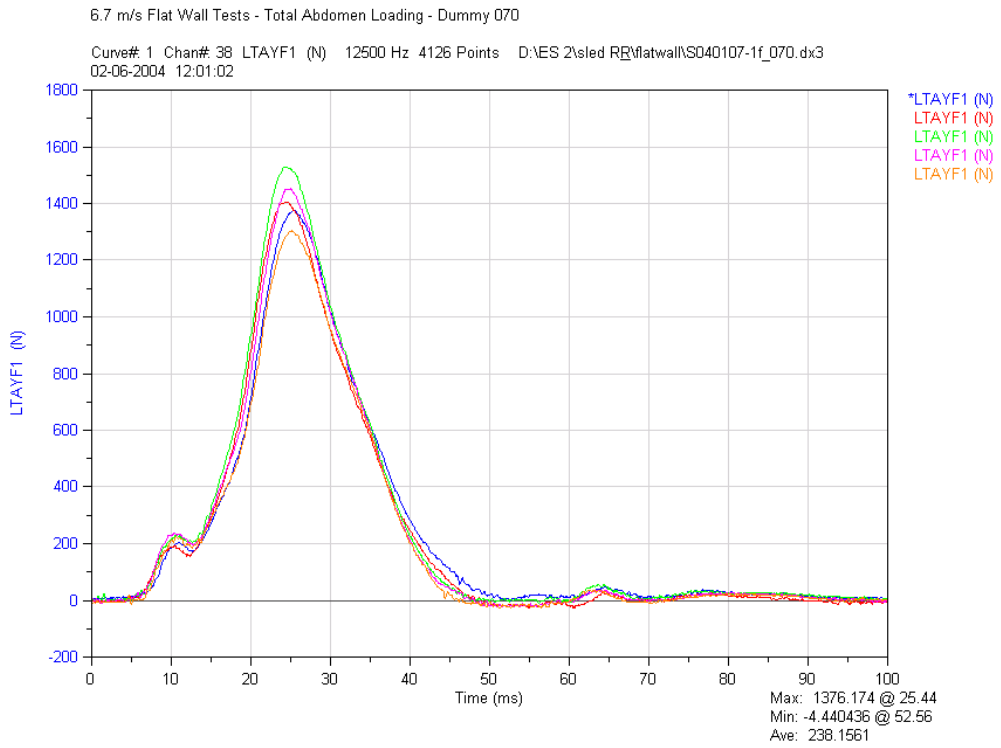

Figure B.18.a. Total Abdomen Loading – Dummy 070

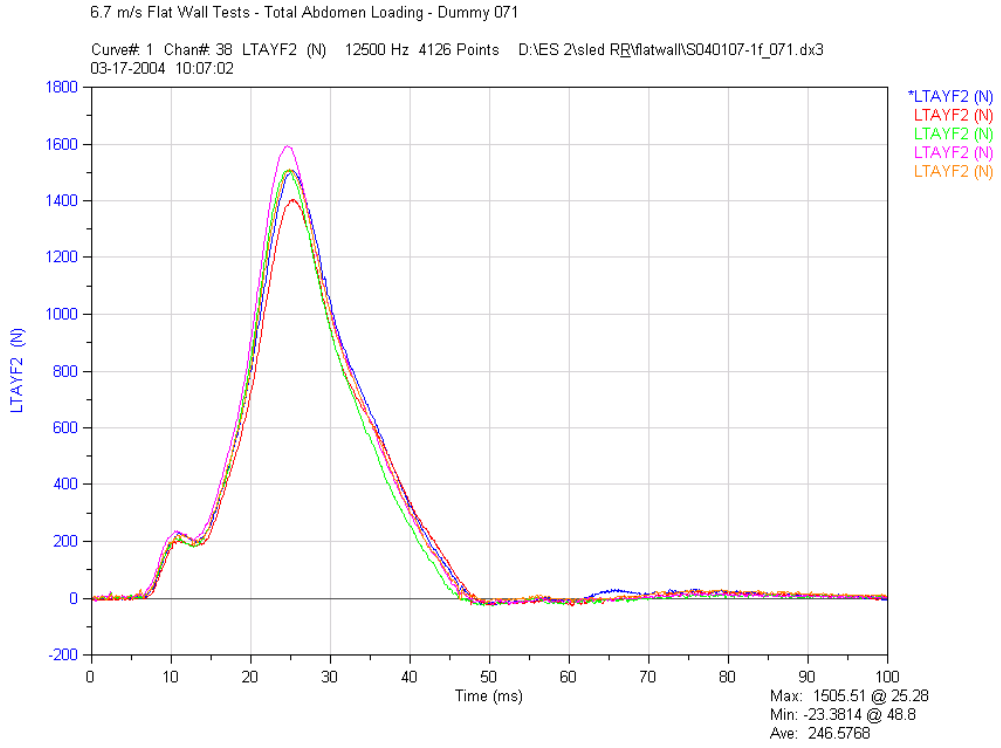

Figure B.18.b. Total Abdomen Loading – Dummy 071

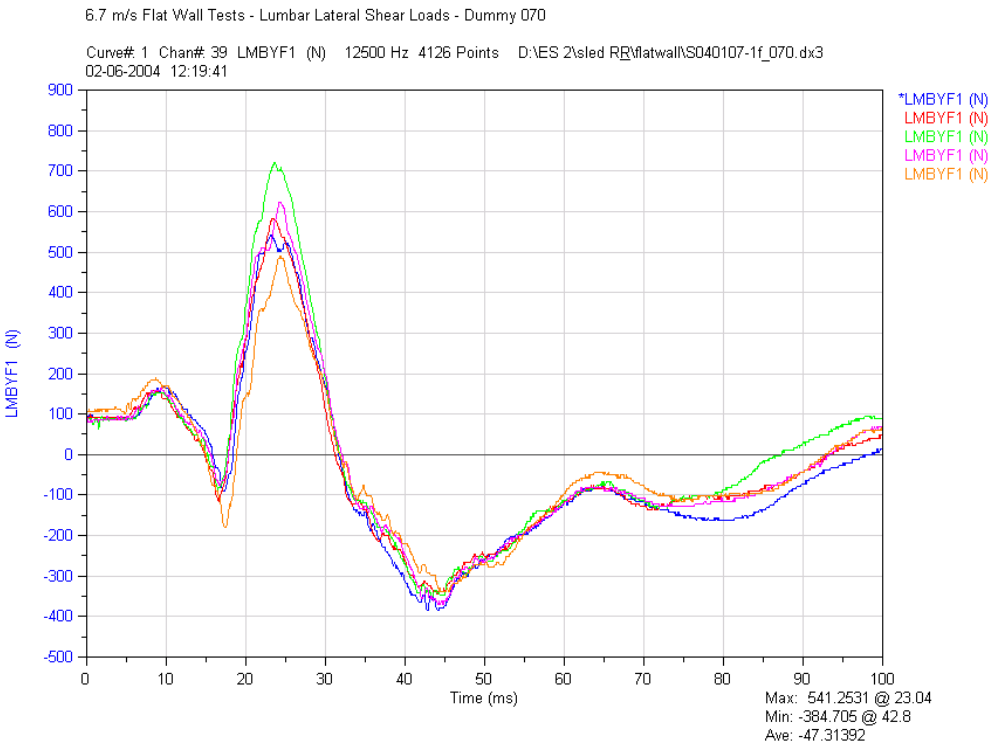

Figure B.19.a. Lumbar Lateral Shear Loads – Dummy 070

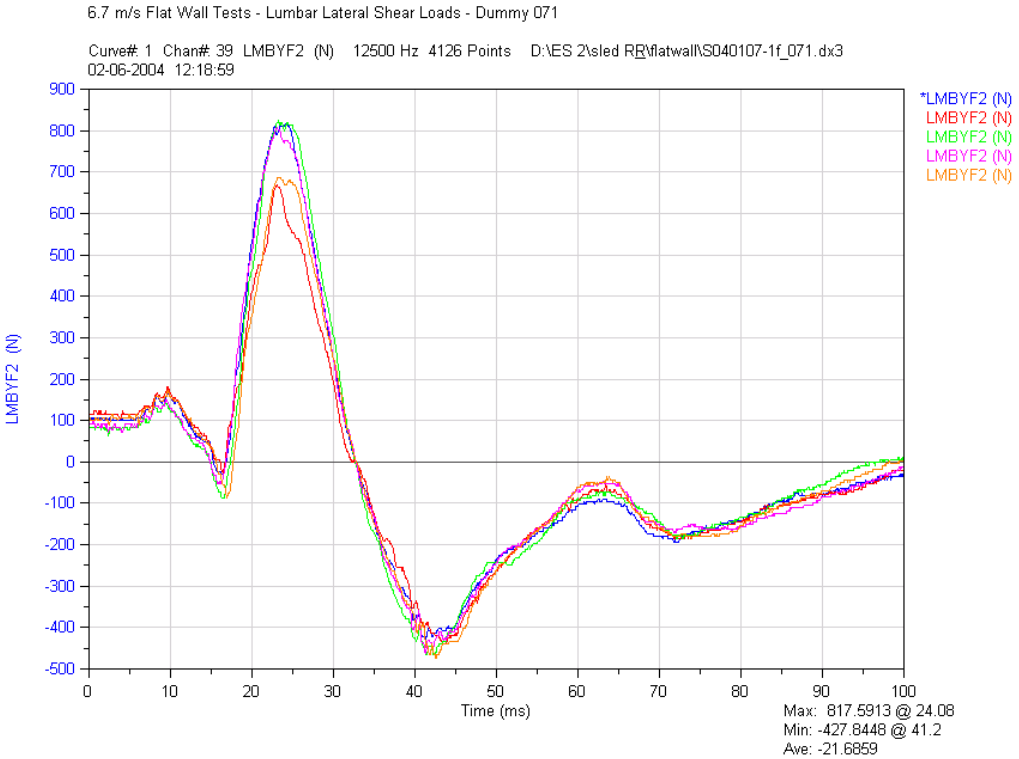

Figure B.19.b. Lumbar Lateral Shear Loads – Dummy 071

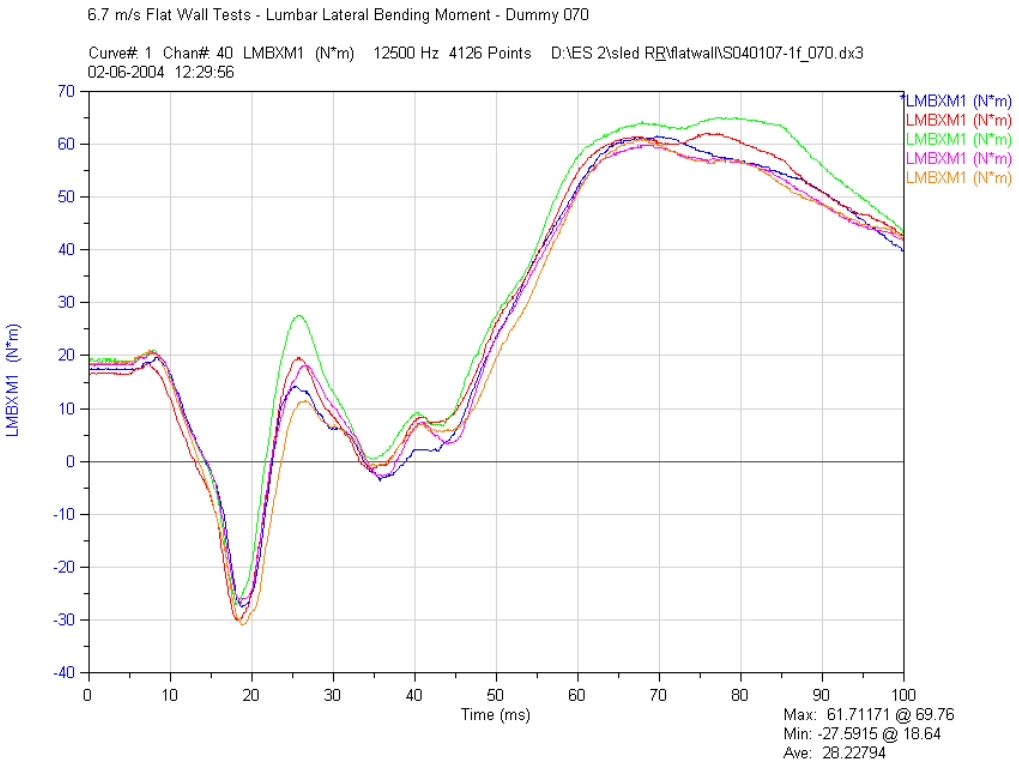

Figure B.20.a. Lumbar Lateral Bending Moment – Dummy 070

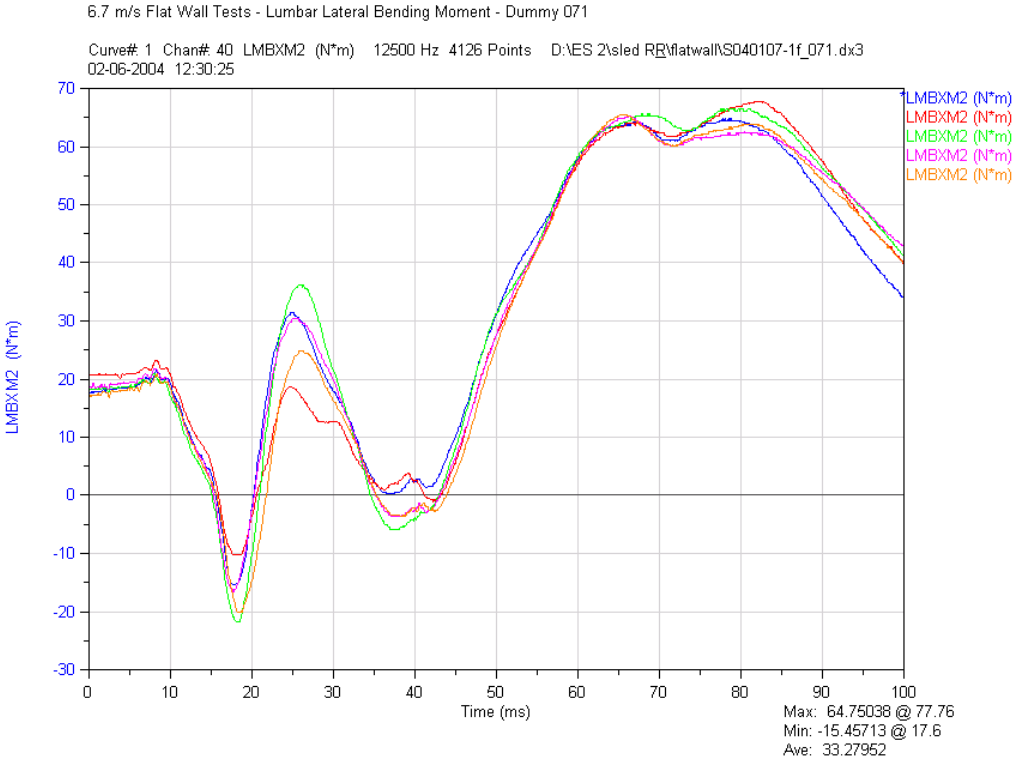

Figure B.20.b. Lumbar Lateral Bending Moment – Dummy 071

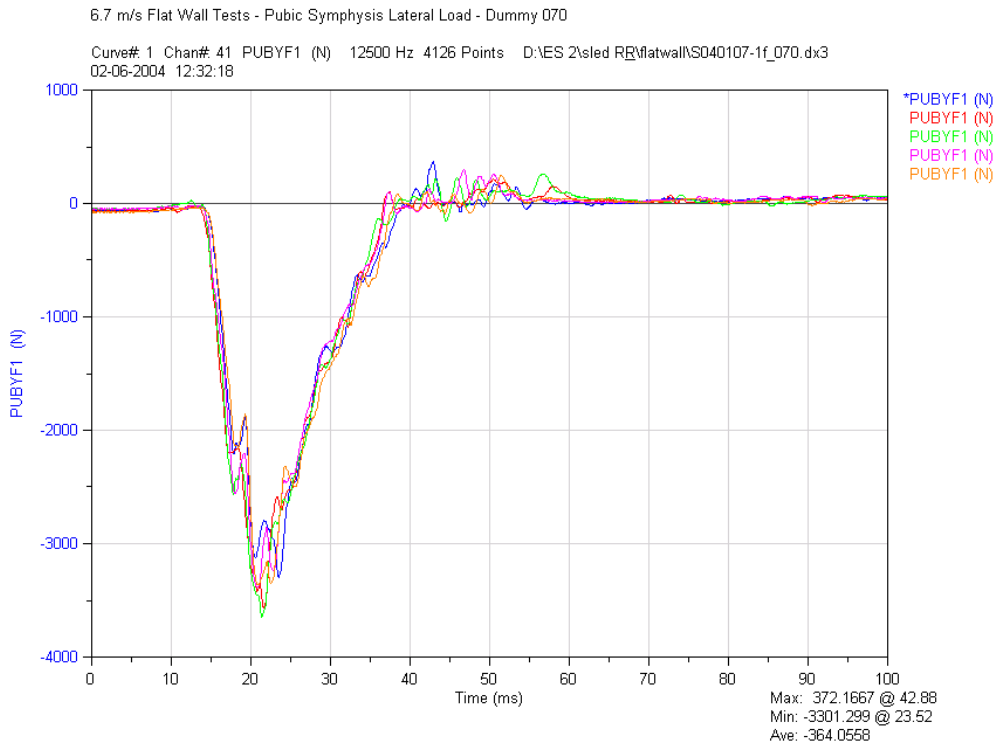

Figure B.21.a. Pubic Symphysis Load – Dummy 070

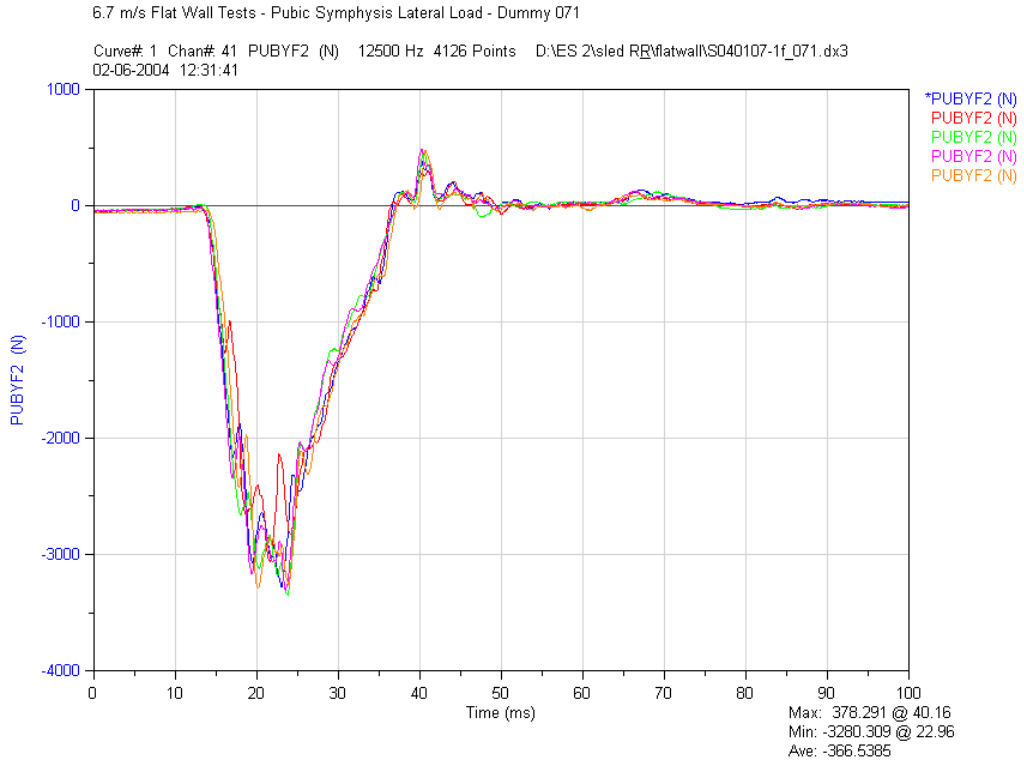

Figure B.21.b. Pubic Symphysis Load – Dummy 071

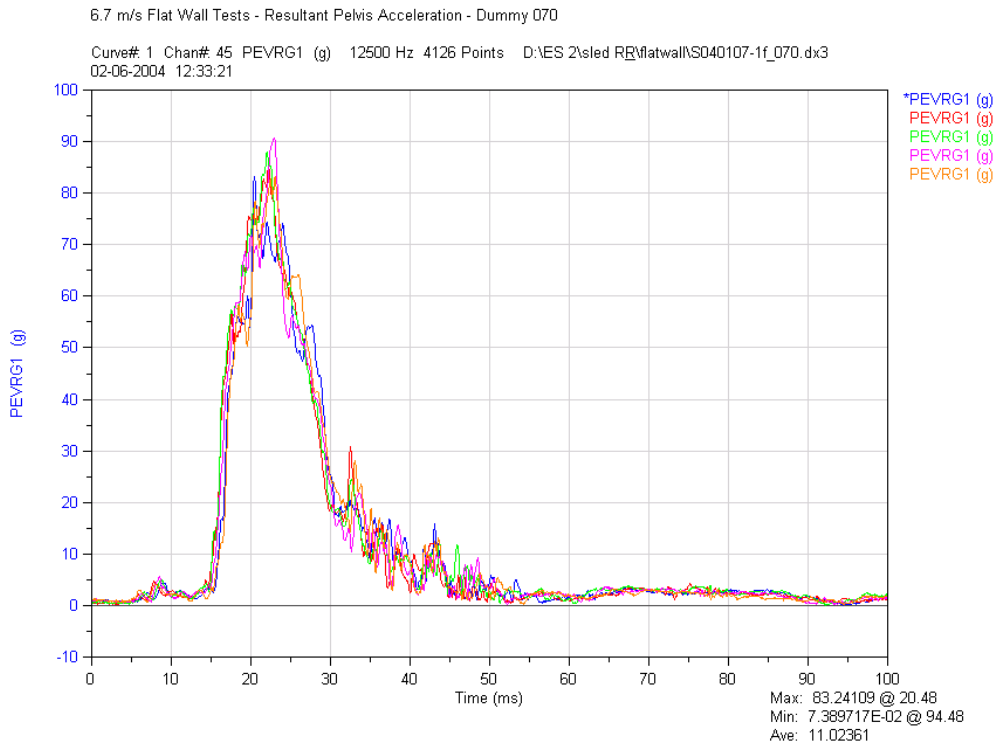

Figure B.22.a. Resultant Pelvis Acceleration – Dummy 070

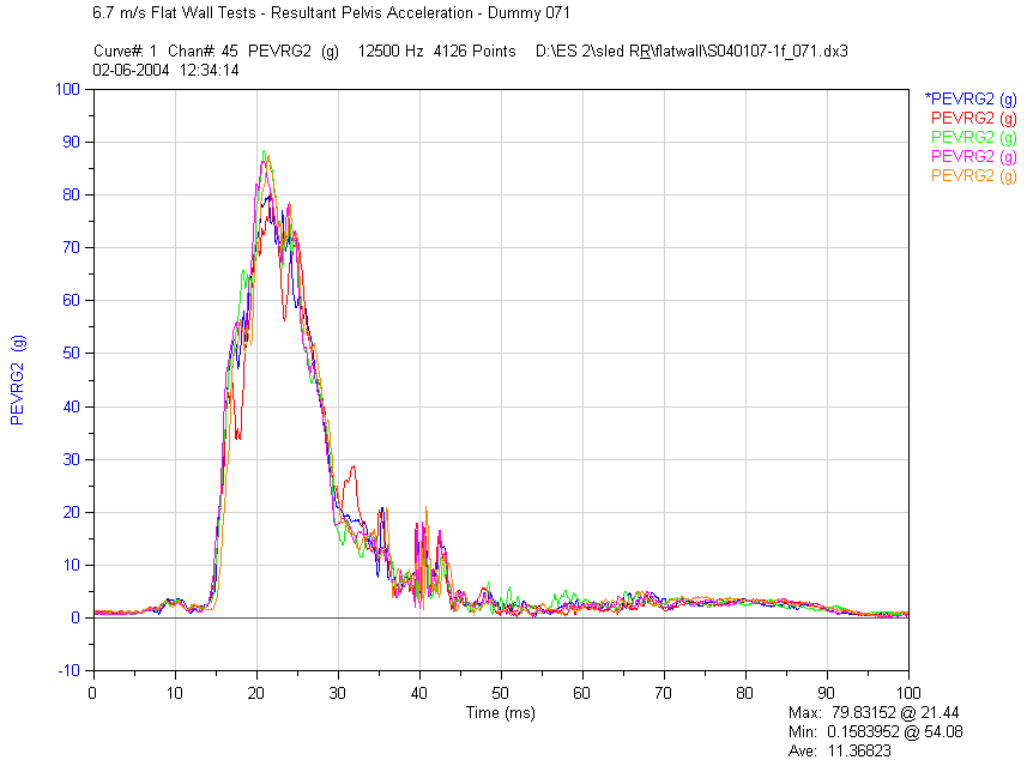

Figure B.22.b. Resultant Pelvis Acceleration – Dummy 071

APPENDIX C: 6.7 m/s Abdomen Offset Sled Test Responses

Table C.1. Summary of Peak Responses in 6.7 m/s Abdomen Offset Sled Tests

		Dummy SN		070					071				
		Dummy Location		Front	Front	Front	Front	Front	Rear	Rear	Rear	Rear	Rear
Location	**Measurement**	**Direction**	**Units**	S040109-1	S040112-1	S040112-2	S040113-1	S040113-2	S040109-1	S040112-1	S040112-2	S040113-1	S040113-2
Head CG	Acceleration	Y	g	21.6	20.9	21.6	21.0	20.9	21.2	20.9	19.5	20.7	19.0
		Z	g	31.1	28.9	29.6	31.6	28.9	31.2	30.9	28.0	29.5	26.3
		Resultant	g	36.0	34.6	35.7	36.7	34.8	36.9	36.4	32.9	35.1	30.7
	HIC-36	Resultant		55.6	50.7	49.3	53.1	51.9	59.9	59.1	51.2	55.1	55.6
Head	Displacement (Front Camera)	Lateral	mm	346.5	350.7	352.3	347.2	356.6	340.8	344.6	361.9	356.6	360.1
		Vertical	mm	-150.3	-142.4	-147.4	-154.4	-145.6	-155.9	-162.6	-159.8	-155.9	-149.5
Upper Neck	Force	Y	N	589.5	578.4	573.3	579.4	564.8	600.1	577.8	534.6	562.9	525.3
		Z	N	1056.5	937.1	938.2	986.4	901.5	1092.3	1041.7	944.5	982.9	866.7
	Moment	+X	N-m	64.9	63.6	61.9	62.5	62.8	60.9	60.8	59.8	58.7	56.6
		-X	N-m	-80.9	-84.4	-83.3	-82.0	-83.2	-80.0	-81.2	-80.6	-81.4	-82.0
Shoulder	Force	Y	N	-883.7	-887.9	-864.5	-876.1	-863.6	-838.0	-857.1	-879.2	-843.0	-813.5
T1	Acceleration	Y	g	70.1	69.1	67.6	66.8	67.8	73.0	74.1	68.7	69.5	65.9
		Resultant	g	70.3	69.2	67.7	67.2	68.0	73.0	74.1	68.7	69.5	66.0
T12	Acceleration	Y	g	85.2	90.1	90.6	90.6	90.0	92.9	93.1	93.8	95.4	95.5
		Resultant	g	85.5	90.3	90.8	90.8	90.1	93.4	93.9	94.4	96.0	96.0
Upper Rib	Displacement	Y	mm	24.0	20.8	20.6	21.9	21.1	26.5	26.4	24.6	24.8	23.7
Middle Rib	Displacement	Y	mm	14.7	13.3	13.5	14.3	13.9	14.7	14.9	13.7	14.1	12.9
Lower Rib	Displacement	Y	mm	14.2	12.1	12.0	12.7	12.4	11.0	10.8	9.7	10.4	9.5
Abdomen-Front	Force	Y	N	842.2	1140.9	1162.1	1164.1	1187.4	943.7	1293.5	1409.5	1339.1	1443.1
Abdomen-Center	Force	Y	N	3004.1	3803.1	3824.1	3707.7	3902.8	3436.8	3975.5	4264.1	4277.4	4606.0
Abdomen-Rear	Force	Y	N	1615.5	1765.7	1715.4	1641.2	1734.6	1800.0	1736.4	1784.2	1887.6	1969.0
Abdomen-Sum	Force	Y	N	5422.8	6685.0	6681.6	6496.6	6804.6	6142.4	6993.0	7432.6	7475.6	7993.5
Lumbar	Force	Y	N	-2337.9	-2759.0	-2909.2	-2856.0	-2921.4	-2275.7	-2569.2	-2582.6	-2574.9	-2628.3
	Moment	+X	N-m	54.6	63.6	65.9	67.3	67.3	41.7	45.8	51.3	51.8	46.0
	Moment	-X	N-m	-125.7	-150.3	-154.0	-148.0	-153.5	-120.4	-128.7	-132.3	-135.3	-136.7
Pubic Symphysis	Force	Y	N	-2448.4	-2611.3	-2411.4	-2584.9	-2502.8	-2275.7	-2357.6	-2650.5	-2516.6	-2598.9
Pelvis	Acceleration	Y	g	98.0	102.8	99.8	97.6	99.6	98.0	102.7	106.8	108.8	109.0
		Resultant	g	98.7	102.8	102.3	102.0	101.4	98.9	103.8	107.7	109.2	109.1
Sled	Acceleration	X	g	-12.6	-12.7	-12.7	-12.7	-12.7	-12.6	-12.7	-12.7	-12.7	-12.7
Sled	Velocity	X	m/s	-6.7	-6.8	-6.7	-6.8	-6.7	-6.7	-6.8	-6.7	-6.8	-6.7

Table C.2. Statistical Analysis for Final Four 6.7 m/s Abdomen Offset Sled Tests

			Dummy SN	070			071			070 & 071		
			Dummy Location	Front			Rear			Front & Rear		
Location	**Measurement**	**Direction**	**Units**	AVG	SD	%CV	AVG	SD	%CV	AVG	SD	% CV
Head CG	Acceleration	Y	g	21.1	0.3	1.6	20.0	0.9	4.6	20.6	0.9	4.3
		Z	g	29.7	1.3	4.2	28.7	2.0	6.9	29.2	1.6	5.6
		Resultant	g	35.4	1.0	2.7	33.8	2.5	7.5	34.6	2.0	5.7
	HIC-36	Resultant		51.3	1.6	3.2	55.2	3.3	5.9	53.3	3.2	6.0
Head	Displacement (Front Camera)	Lateral	mm	351.7	3.9	1.1	355.8	7.8	2.2	353.8	6.1	1.7
		Vertical	mm	-147.5	5.1	3.4	-157.0	5.7	3.6	-152.2	7.1	4.7
Upper Neck	Force	Y	N	574.0	6.7	1.2	550.2	24.4	4.4	562.1	20.9	3.7
		Z	N	940.8	34.9	3.7	959.0	73.4	7.6	949.9	54.1	5.7
	Moment	+X	N-m	62.7	0.7	1.2	59.0	1.8	3.0	60.8	2.4	3.9
		-X	N-m	-83.2	1.0	1.2	-81.3	0.6	0.7	-82.3	1.3	1.6
Shoulder	Force	Y	N	-873.0	11.5	1.3	-848.2	27.5	3.2	-860.6	23.6	2.7
T1	Acceleration	Y	g	67.9	1.0	1.4	69.5	3.4	4.8	68.7	2.5	3.6
		Resultant	g	68.0	0.9	1.3	69.6	3.4	4.8	68.8	2.4	3.5
T12	Acceleration	Y	g	90.3	0.3	0.4	94.5	1.2	1.2	92.4	2.4	2.5
		Resultant	g	90.5	0.3	0.4	95.1	1.1	1.1	92.8	2.6	2.8
Upper Rib	Displacement	Y	mm	21.1	0.6	2.7	24.9	1.1	4.4	23.0	2.2	9.5
Middle Rib	Displacement	Y	mm	13.7	0.5	3.3	13.9	0.8	5.9	13.8	0.6	4.5
Lower Rib	Displacement	Y	mm	12.3	0.3	2.4	10.1	0.6	5.9	11.2	1.3	11.3
Abdomen-Front	Force	Y	N	1163.6	19.0	1.6	1371.3	67.6	4.9	1267.5	120.1	9.5
Abdomen-Center	Force	Y	N	3809.4	80.3	2.1	4280.7	257.7	6.0	4045.1	307.7	7.6
Abdomen-Rear	Force	Y	N	1714.2	52.9	3.1	1844.3	104.4	5.7	1779.3	103.5	5.8
Abdomen-Sum	Force	Y	N	6666.9	127.2	1.9	7473.7	409.5	5.5	7070.3	514.5	7.3
Lumbar	Force	Y	N	-2861.4	73.9	2.6	-2588.7	26.9	1.0	-2725.1	154.6	5.7
	Moment	+X	N-m	66.0	1.7	2.6	48.7	3.3	6.7	57.4	9.6	16.7
	Moment	-X	N-m	-151.4	2.8	1.9	-133.3	3.6	2.7	-142.4	10.2	7.1
Pubic Symphysis	Force	Y	N	-2527.6	90.2	3.6	-2530.9	128.0	5.1	-2529.3	102.5	4.1
Pelvis	Acceleration	Y	g	100.0	2.1	2.1	106.8	2.9	2.7	103.4	4.4	4.2
		Resultant	g	102.1	0.6	0.6	107.5	2.5	2.4	104.8	3.3	3.2
Sled	Acceleration	X	g	-12.7	0.0	0.2	-12.7	0.0	0.2	-12.7	0.0	0.1
Sled	Velocity	X	m/s	-6.7	0.0	0.2	-6.7	0.0	0.2	-6.7	0.0	0.2

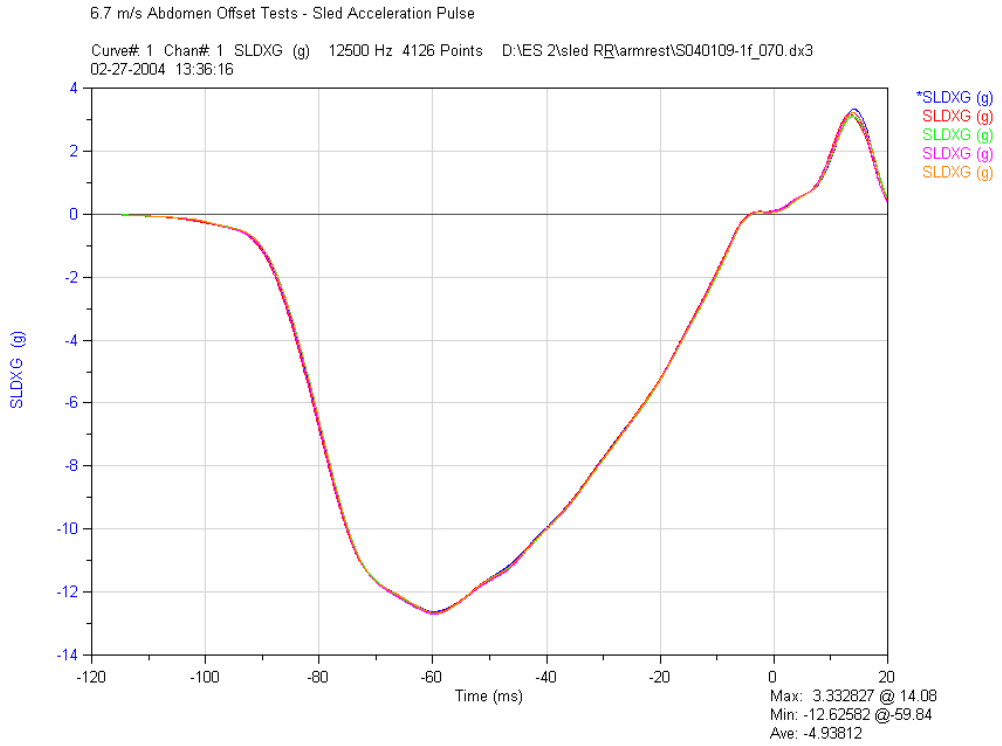

Figure C.1. Sled Acceleration Pulse

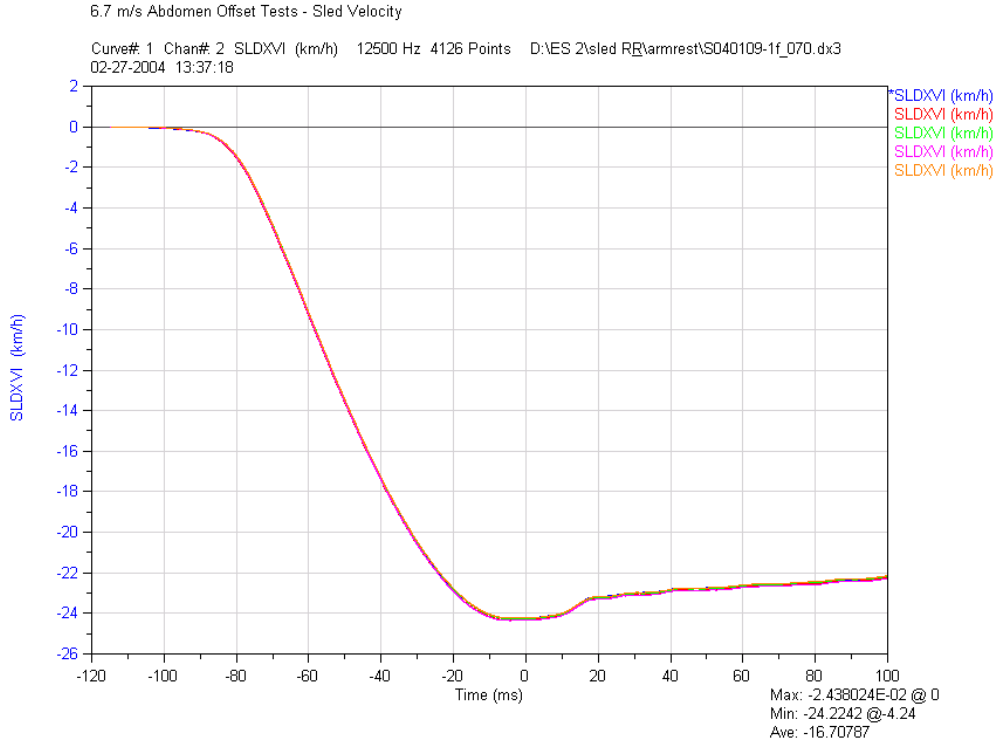

Figure C.2. Sled Velocity

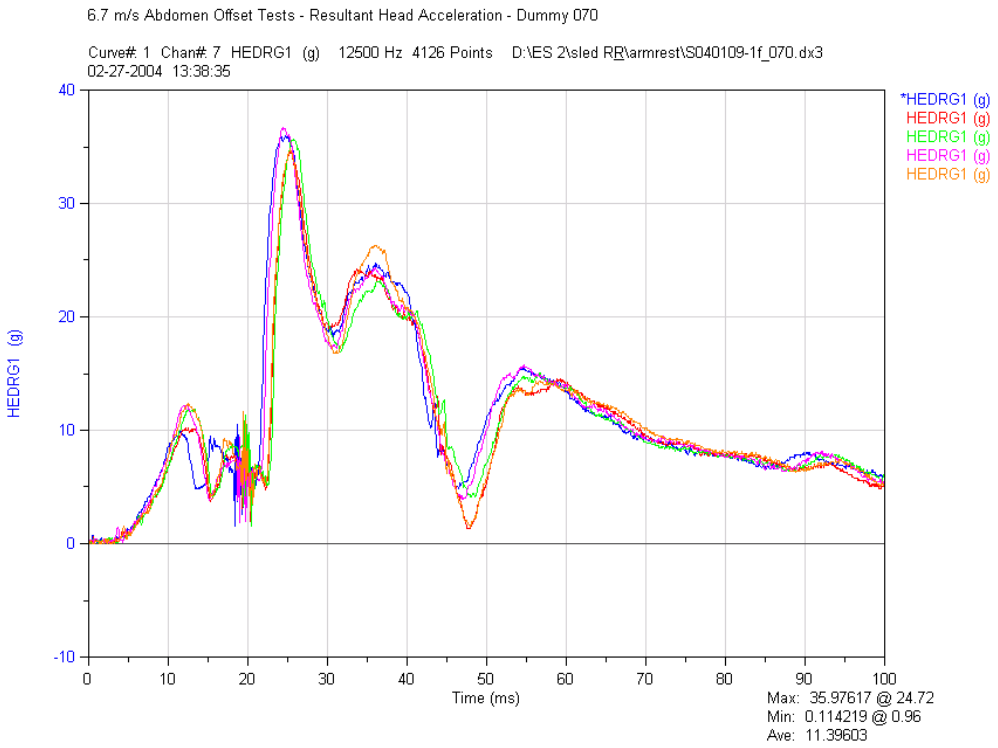

Fig. C.3.a. Resultant Head Acceleration – Dummy 070

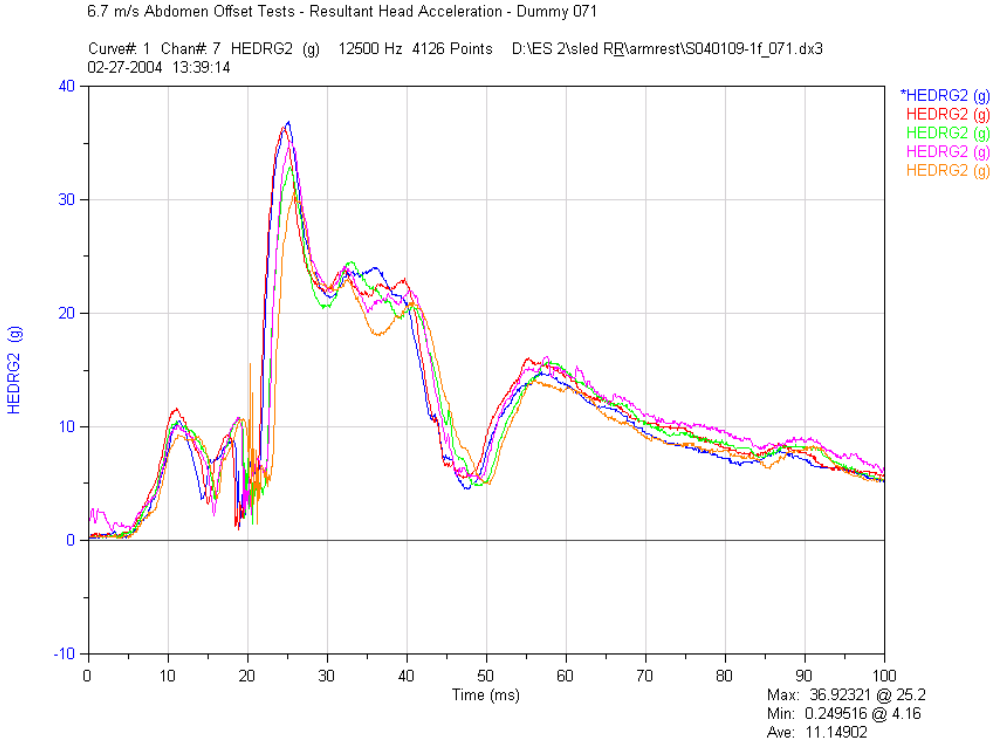

Fig. C.3.b. Resultant Head Acceleration – Dummy 071

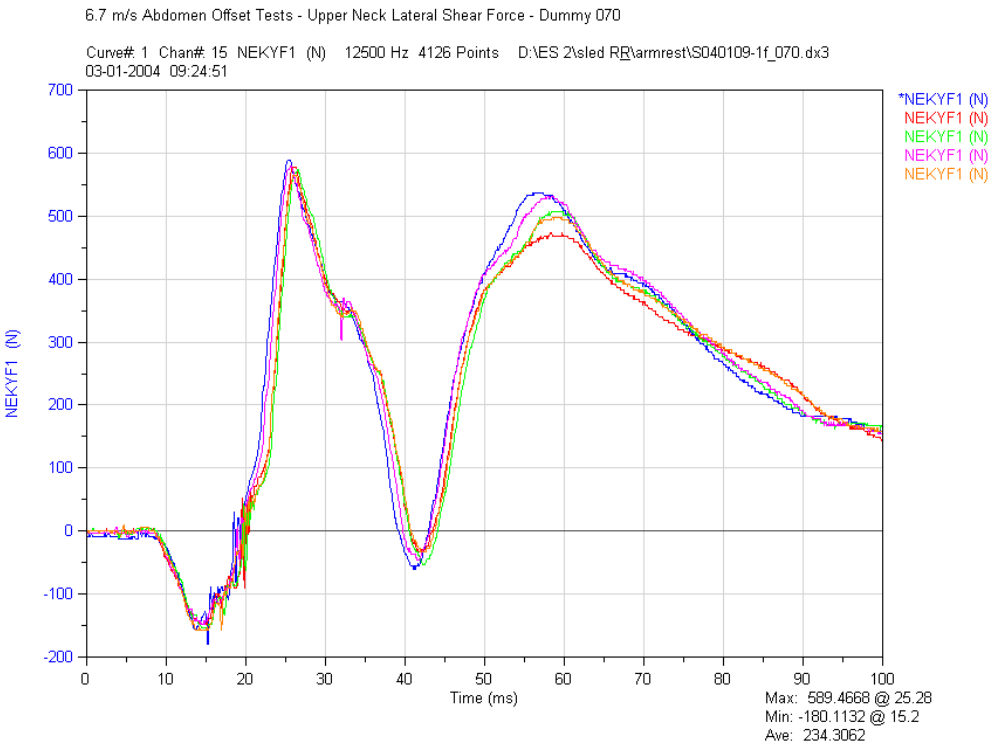

Figure C.4.a. Upper Neck Lateral Shear Force – Dummy 070

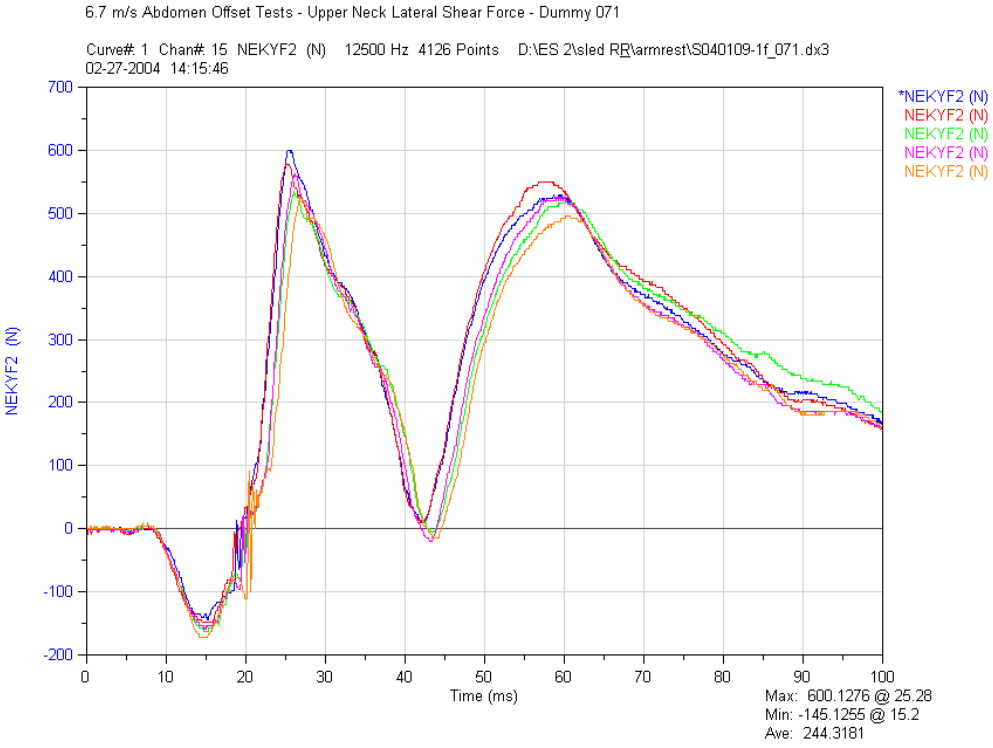

Figure C.4.b. Upper Neck Lateral Shear Force – Dummy 071

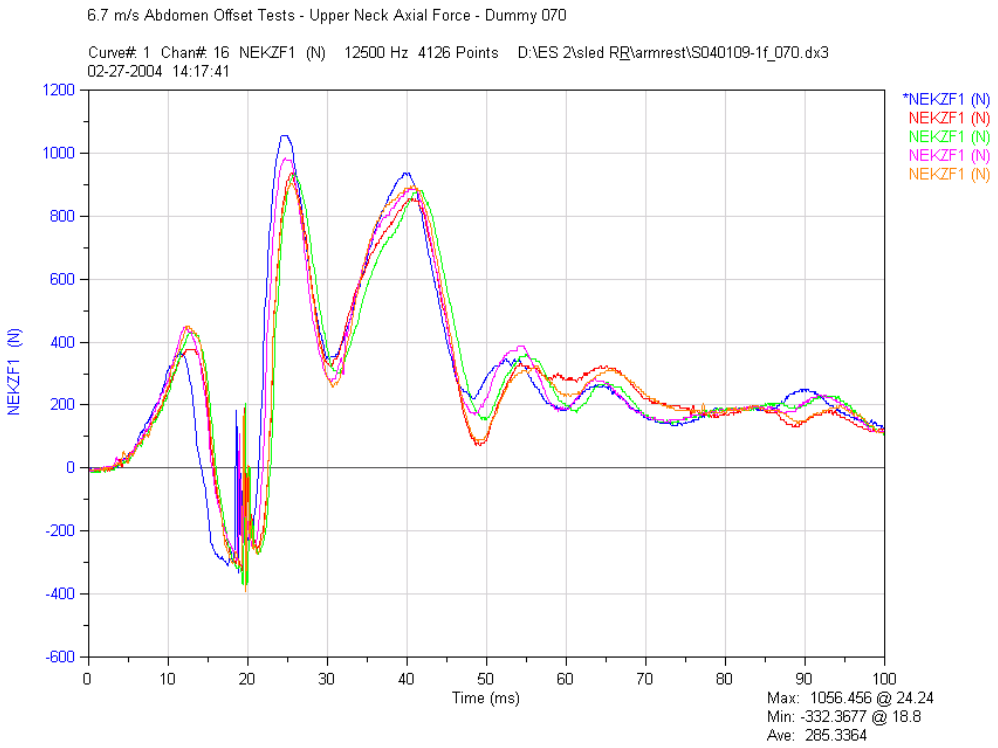

Figure C.5.a. Upper Neck Axial Force – Dummy 070

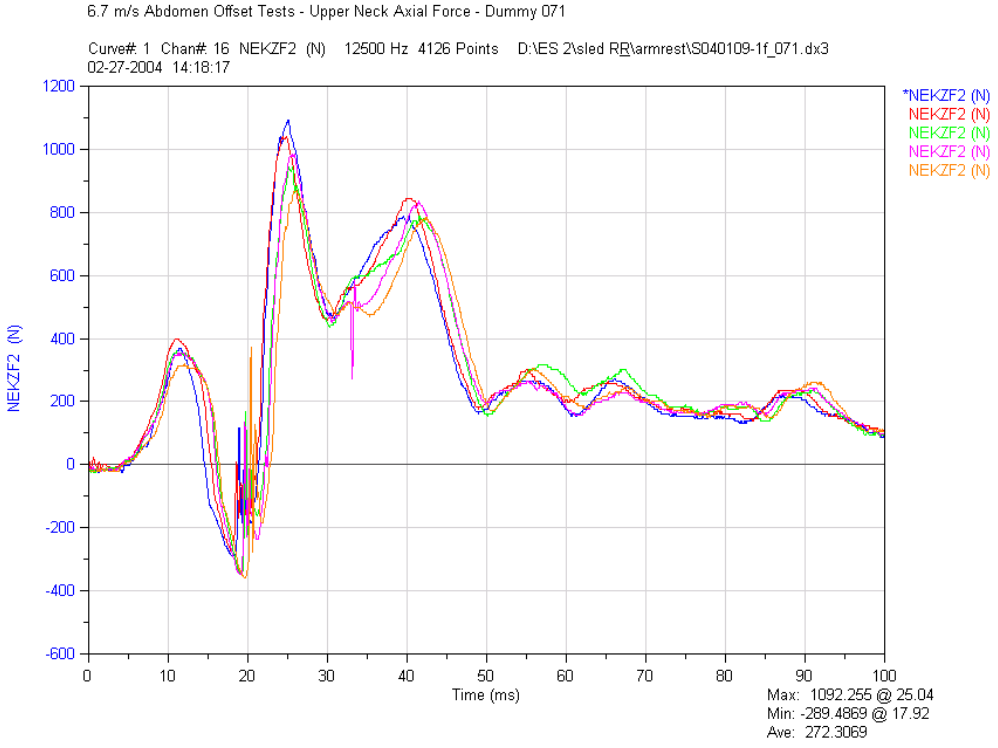

Figure C.5.b. Upper Neck Axial Force – Dummy 071

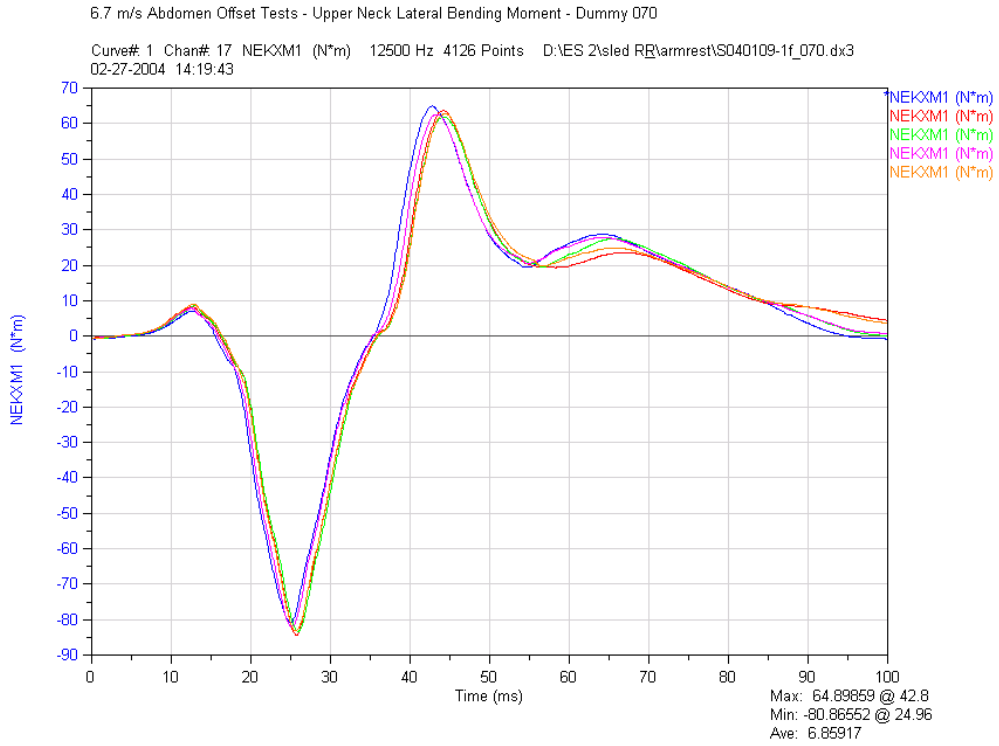

Figure C.6.a. Upper Neck Lateral Bending Moment – Dummy 070

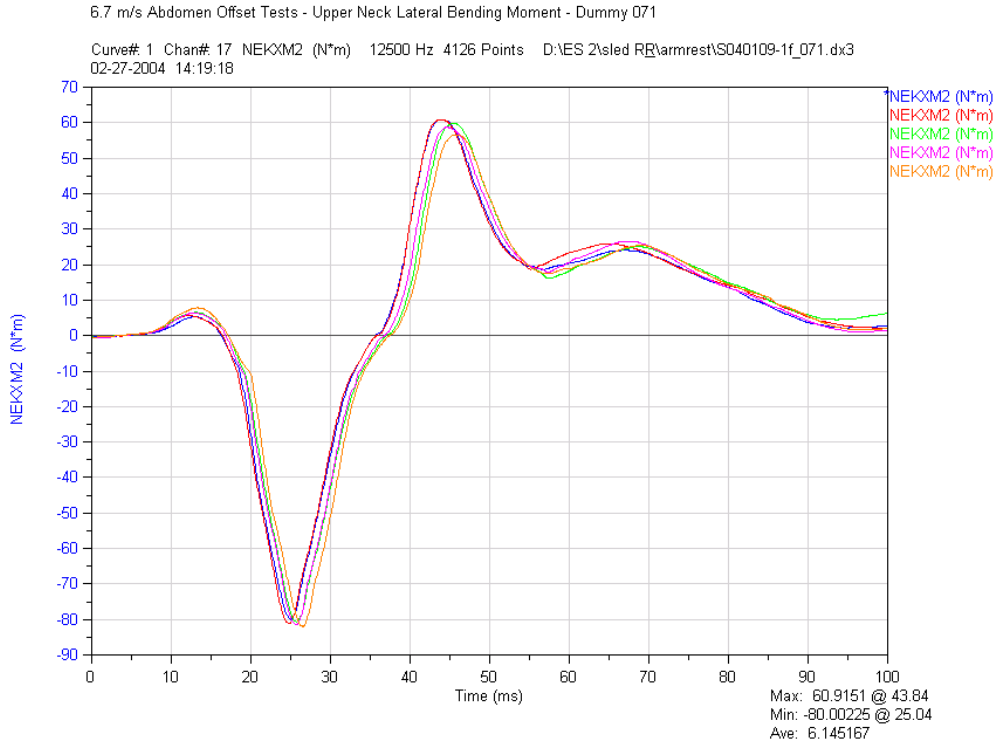

Figure C.6.b. Upper Neck Lateral Bending Moment – Dummy 071

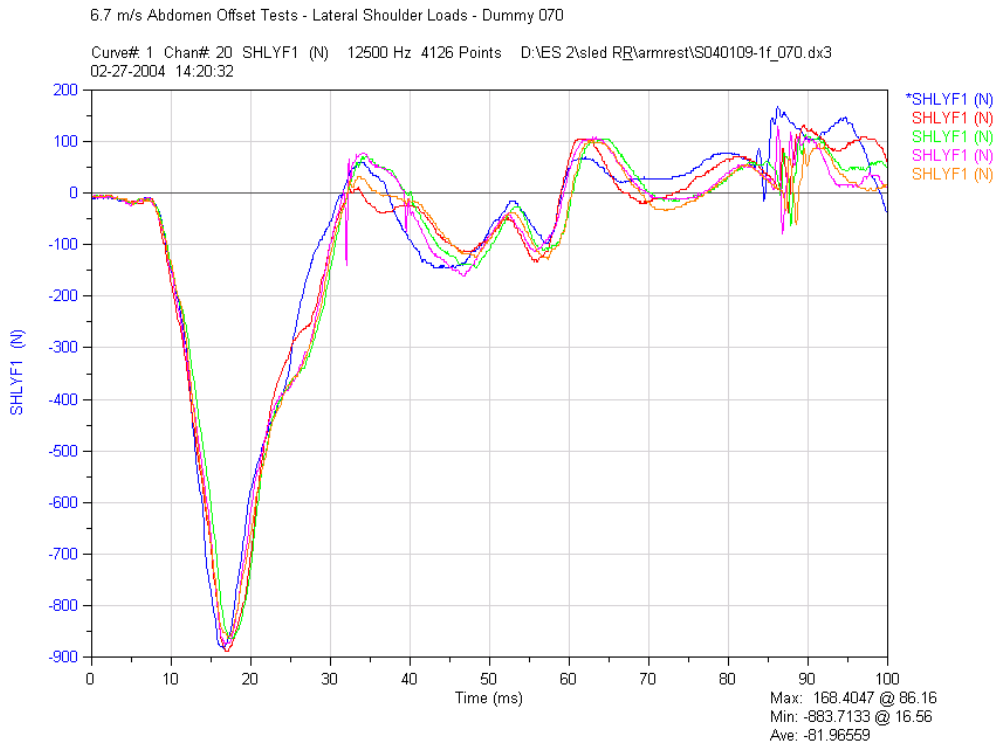

Figure C.7.a. Lateral Shoulder Loads – Dummy 070

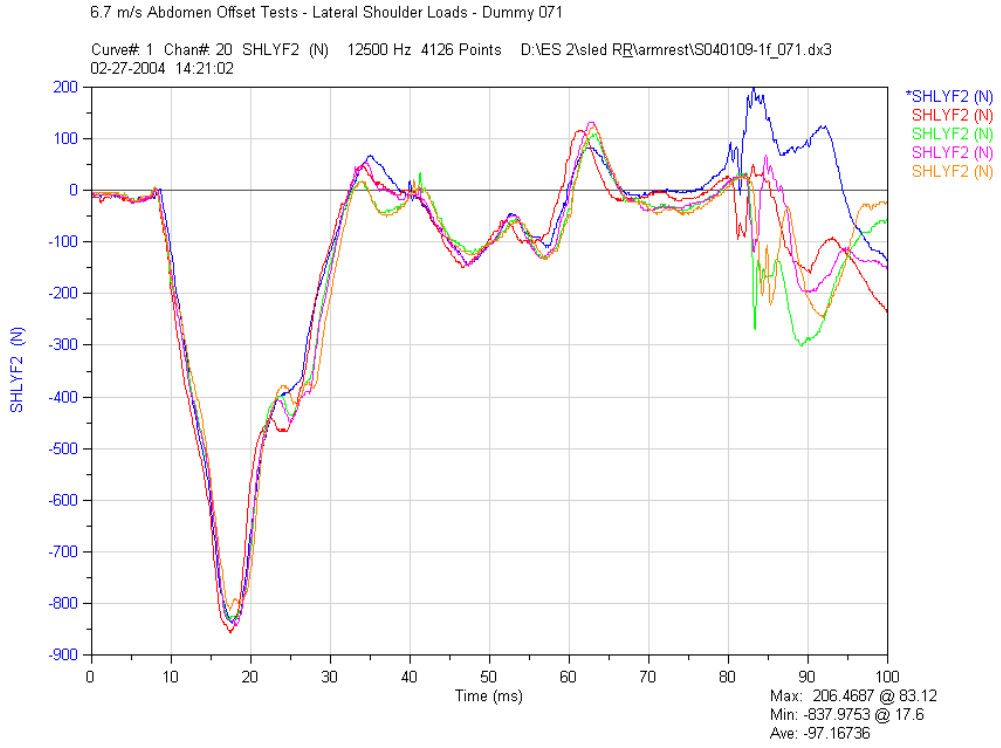

Figure C.7.b. Lateral Shoulder Loads – Dummy 071

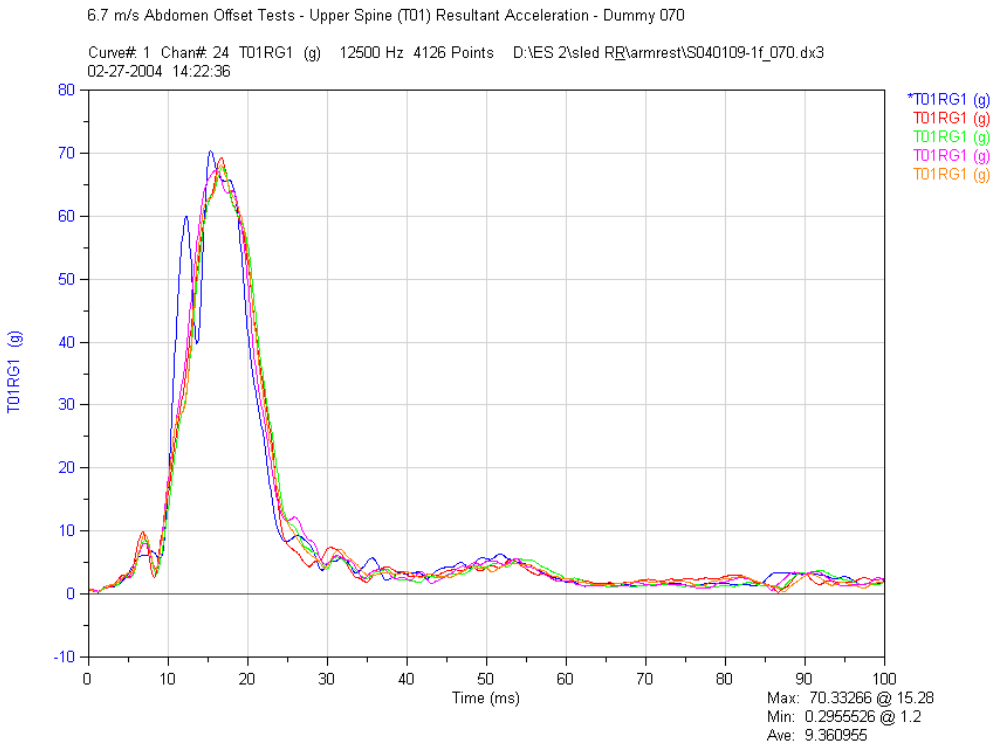

Figure C.8.a. Upper Spine Resultant Acceleration – Dummy 070

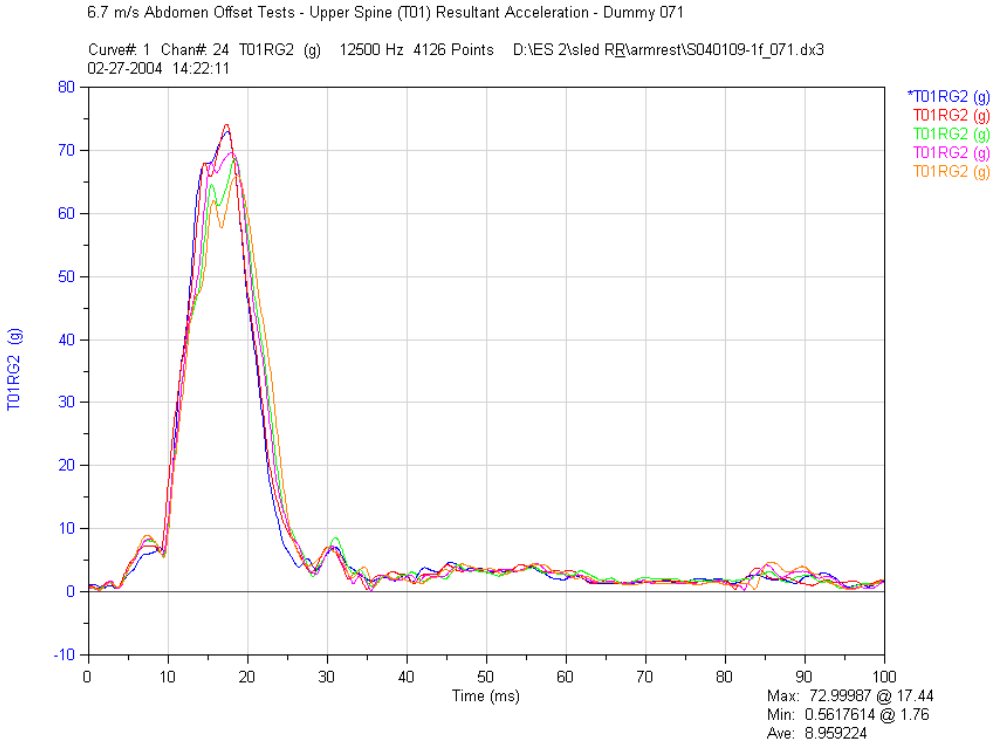

Figure C.8.b. Upper Spine Resultant Acceleration – Dummy 071

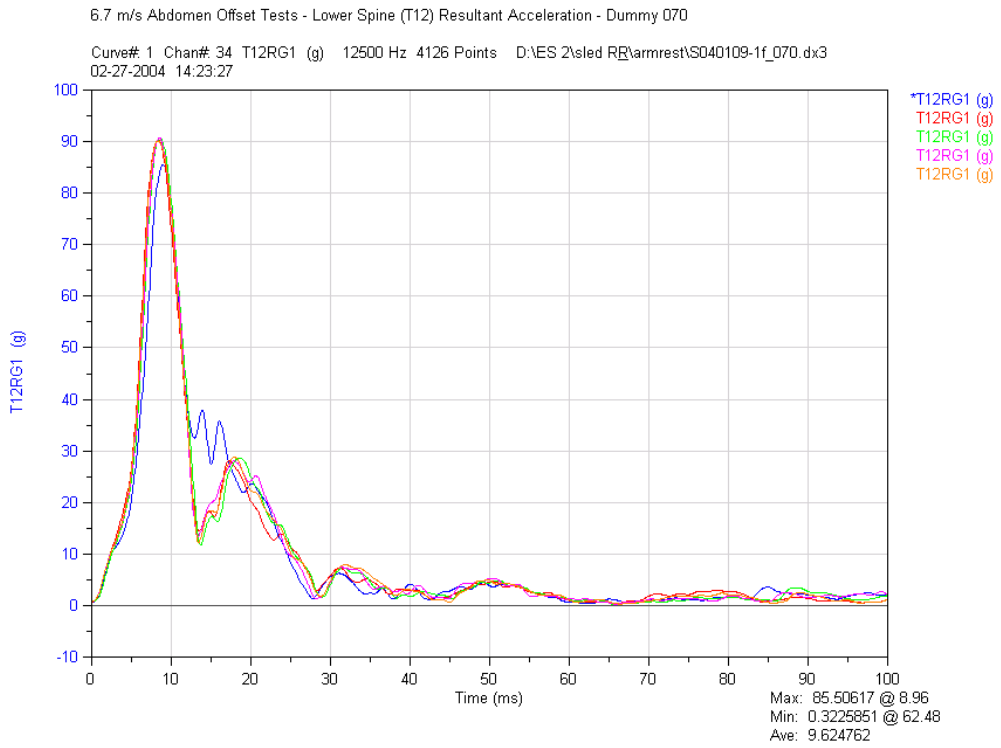

Figure C.9.a. Lower Spine Resultant Acceleration – Dummy 070

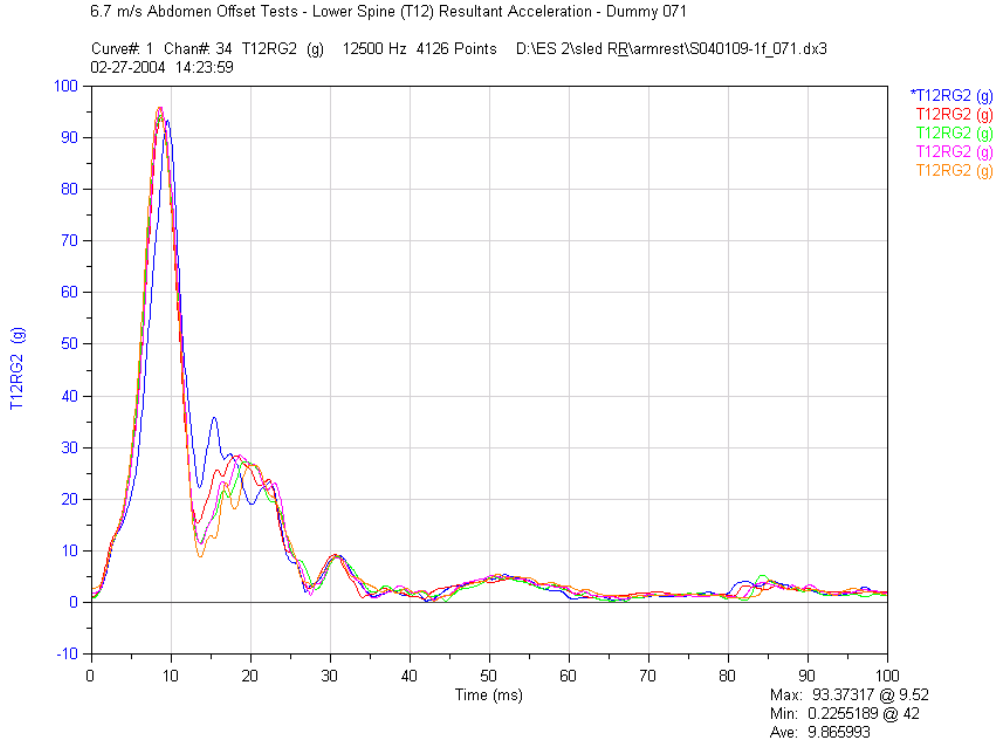

Figure C.9.b. Lower Spine Resultant Acceleration – Dummy 071

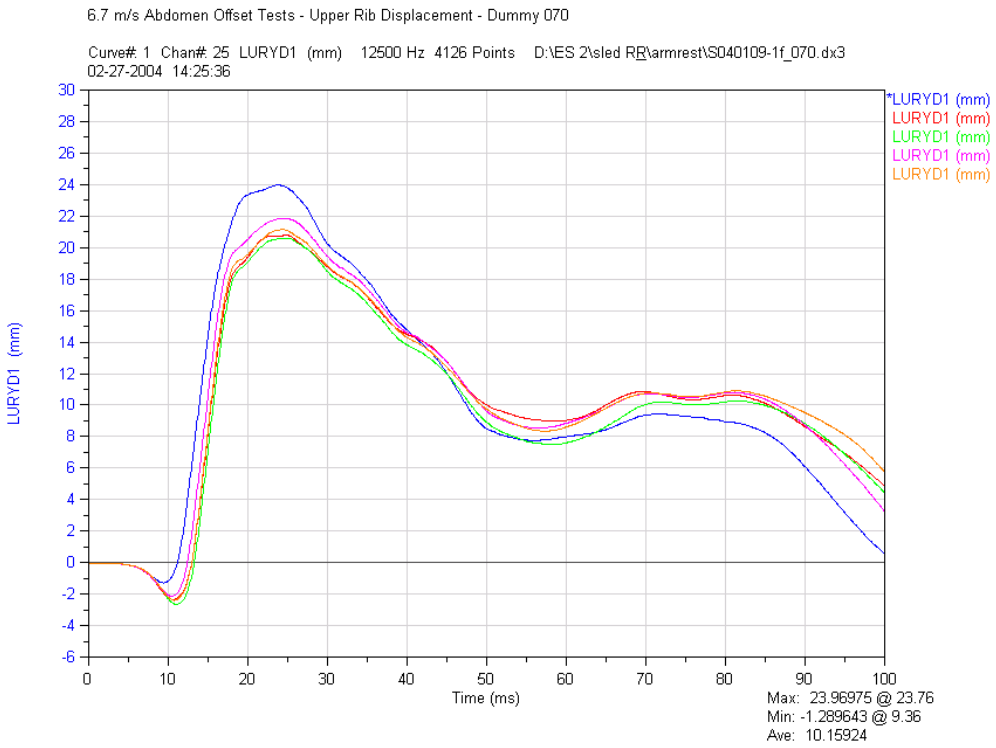

Figure C.10.a. Upper Rib Displacement – Dummy 070

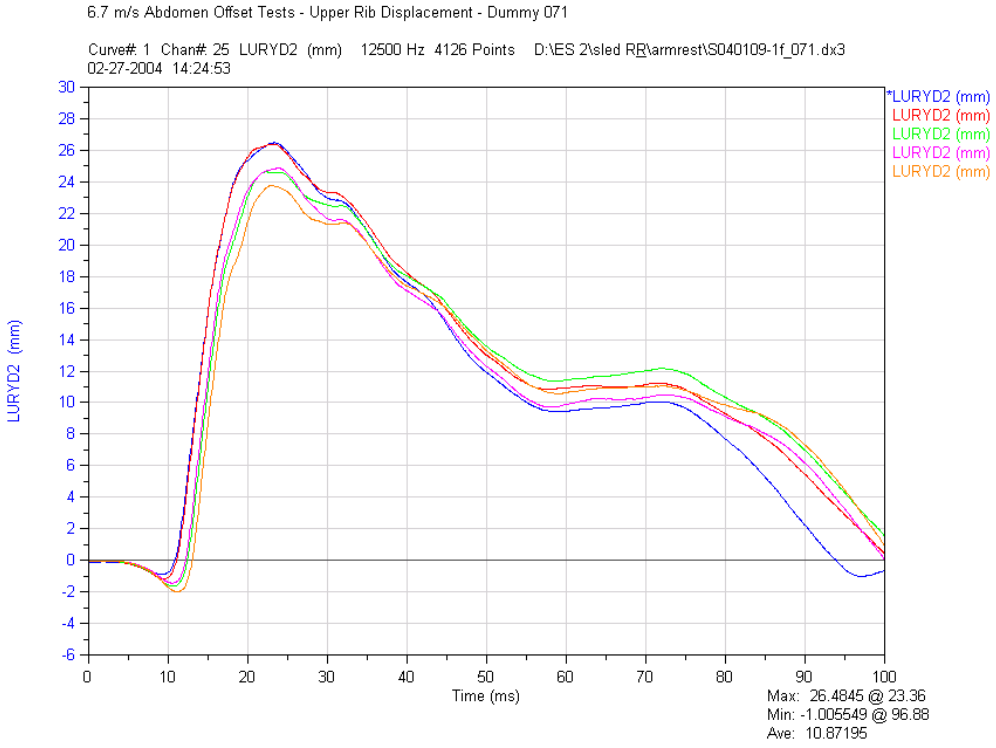

Figure C.10.b. Upper Rib Displacement – Dummy 071

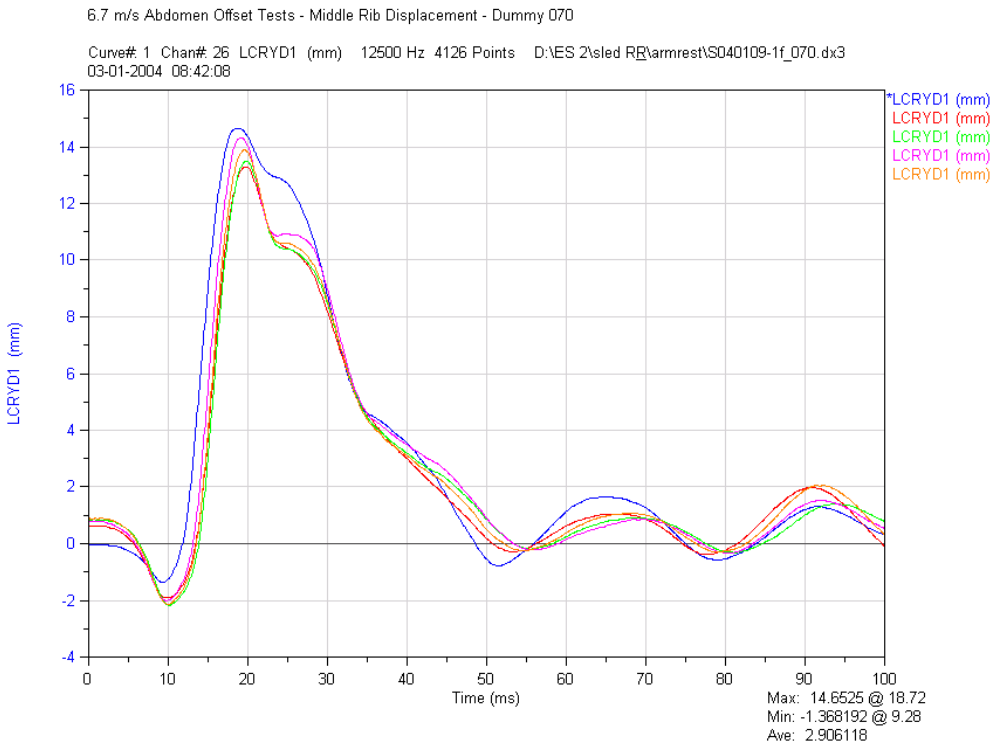

Figure C.11.a. Middle Rib Displacement – Dummy 070

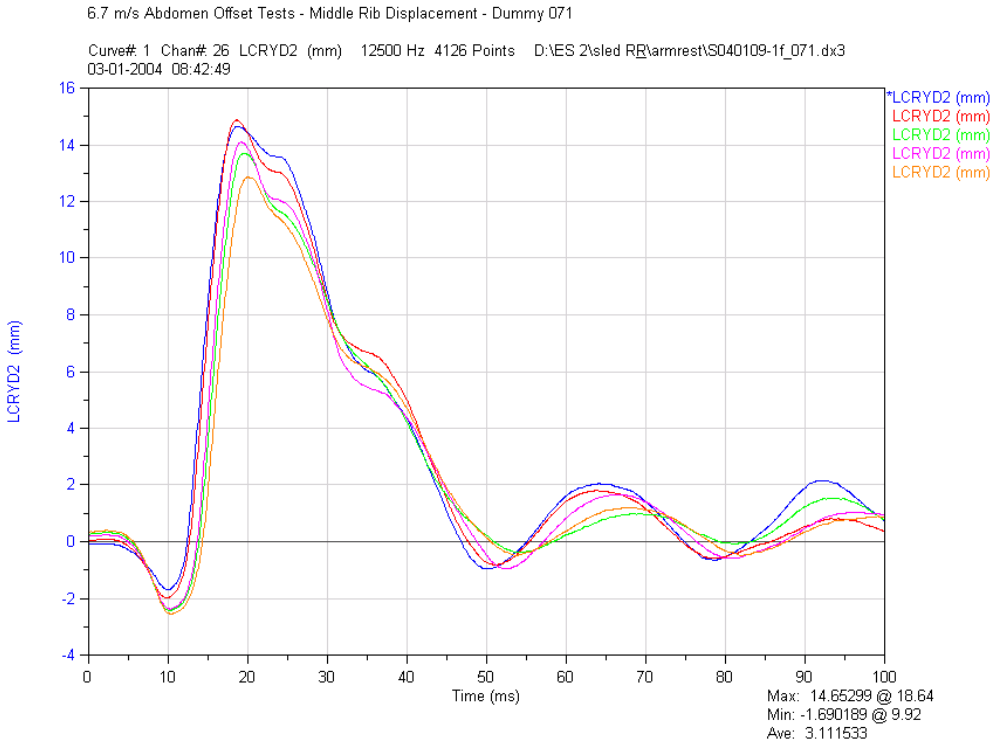

Figure C.11.b. Middle Rib Displacement – Dummy 071

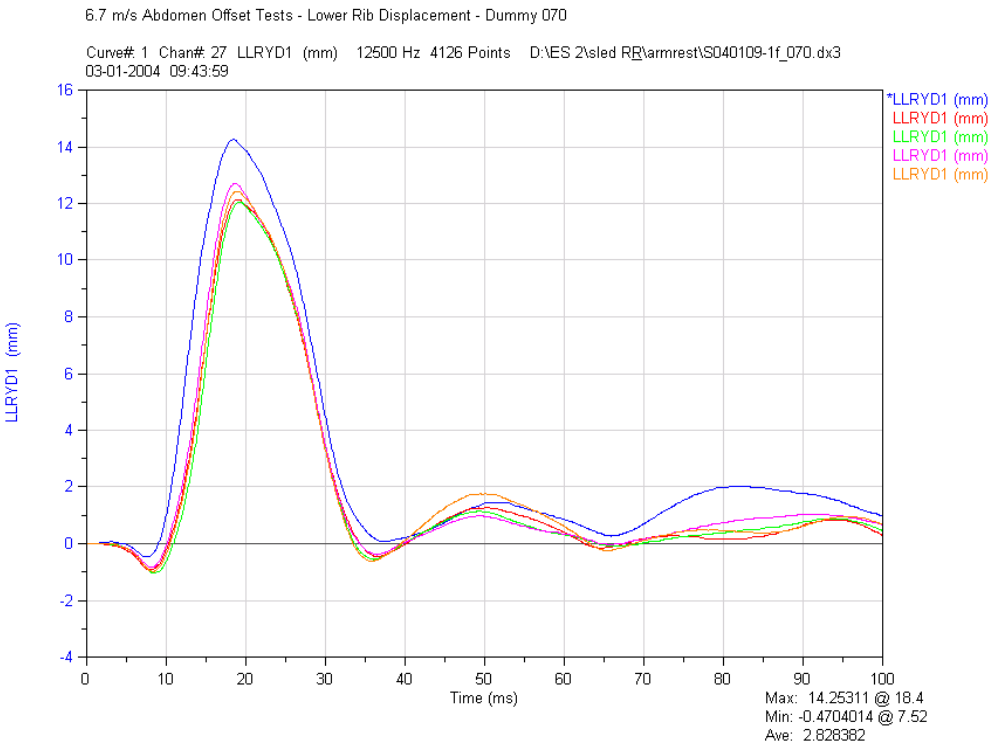

Figure C.12.a. Lower Rib Displacement – Dummy 070

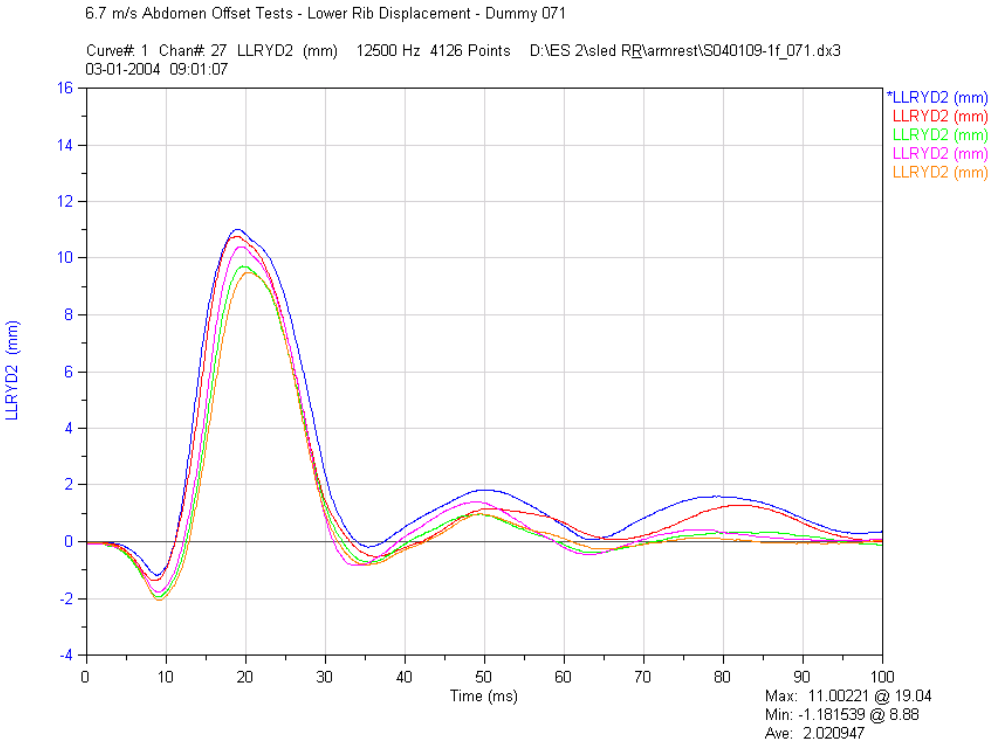

Figure C.12.b. Lower Rib Displacement – Dummy 071

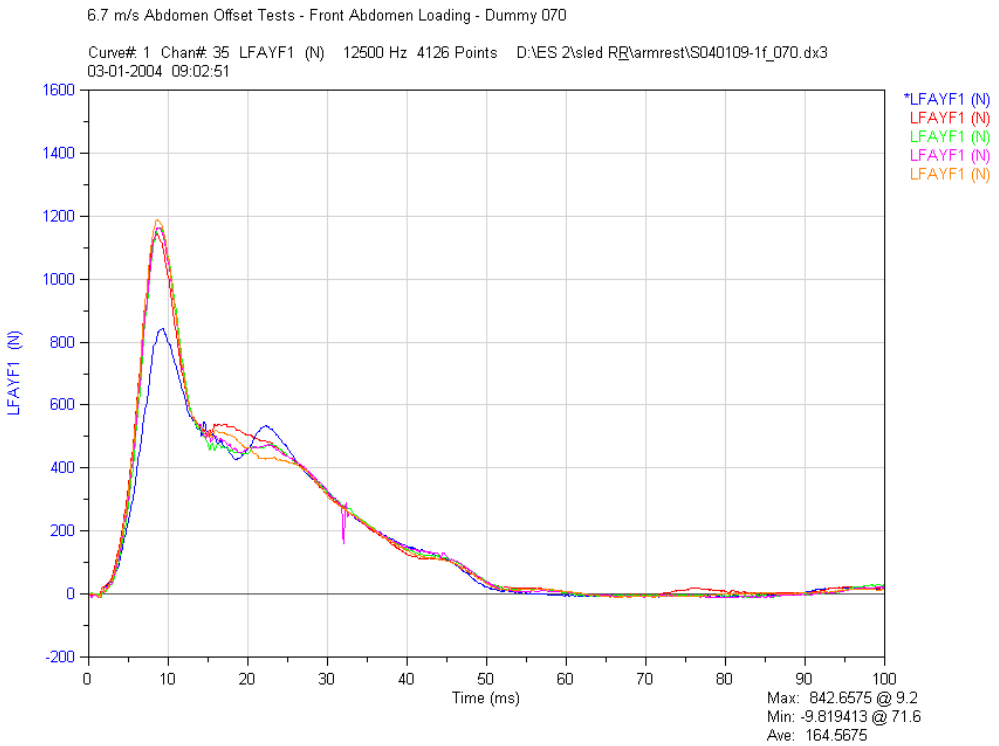

Figure C.13.a. Front Abdomen Loading – Dummy 070

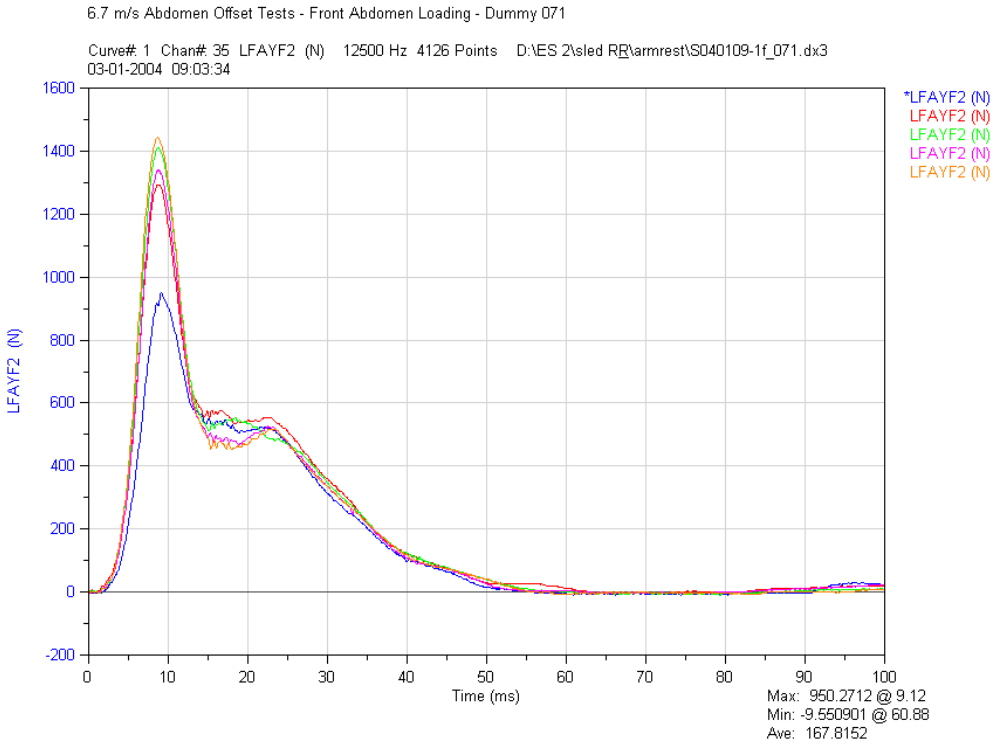

Figure C.13.b. Front Abdomen Loading – Dummy 071

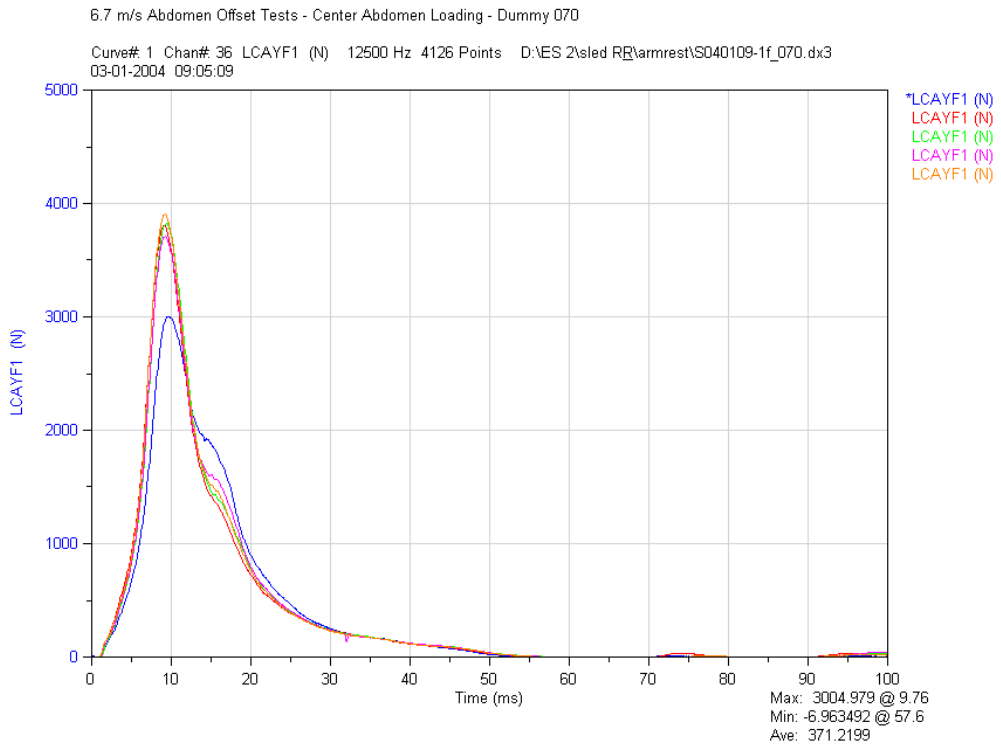

Figure C.14.a. Center Abdomen Loading – Dummy 070

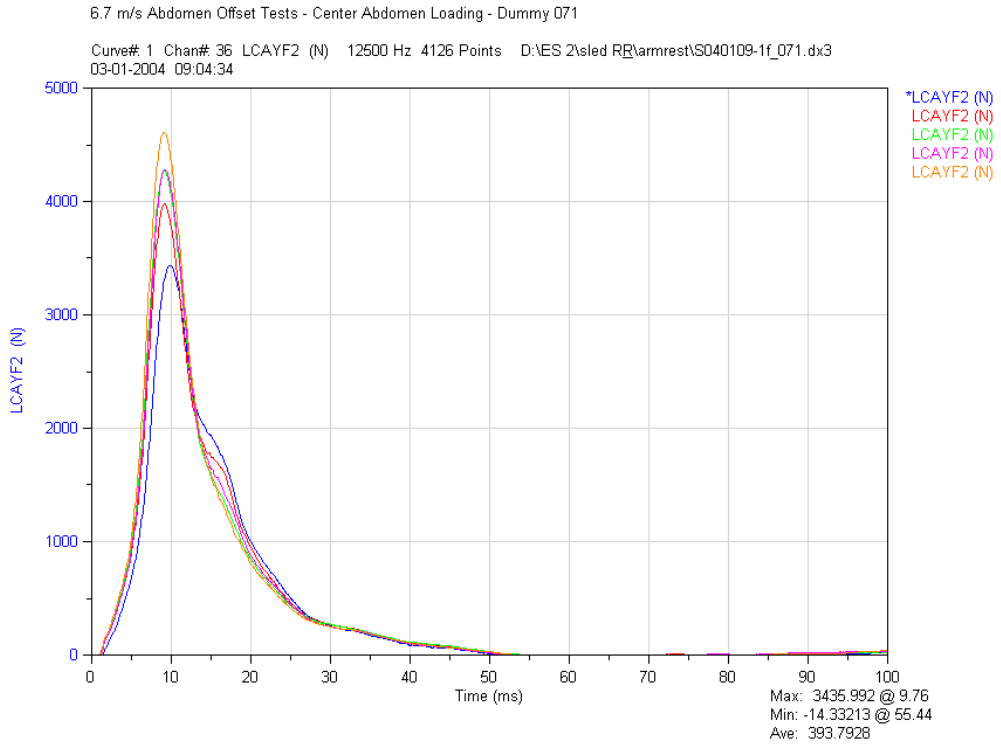

Figure C.14.b. Center Abdomen Loading – Dummy 071

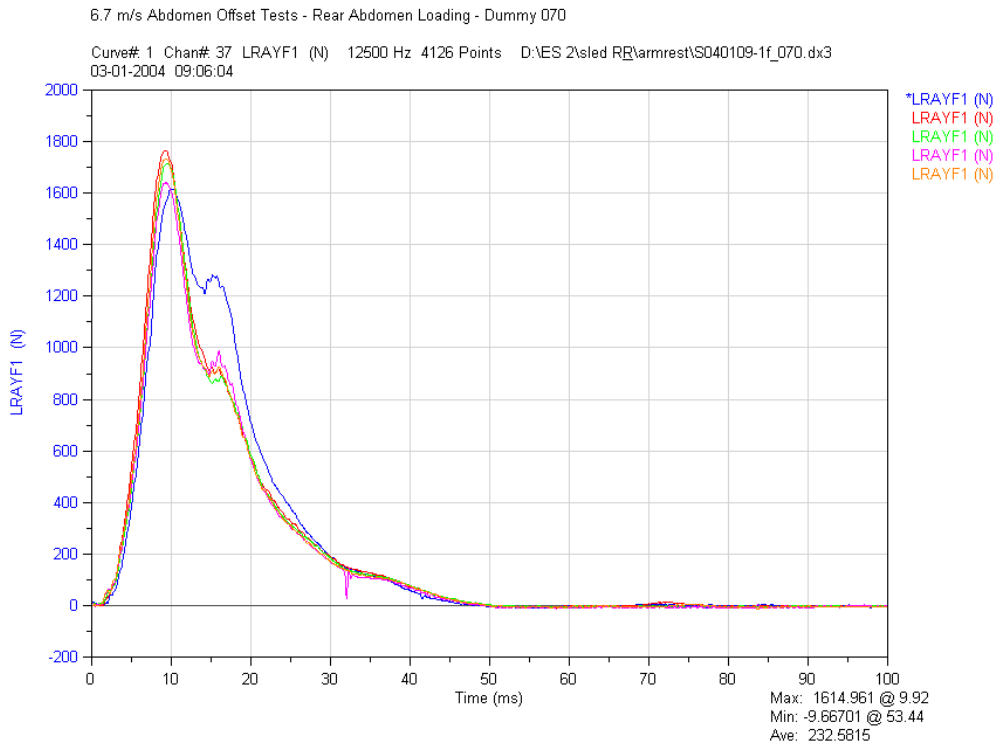

Figure C.15.a. Rear Abdomen Loading – Dummy 070

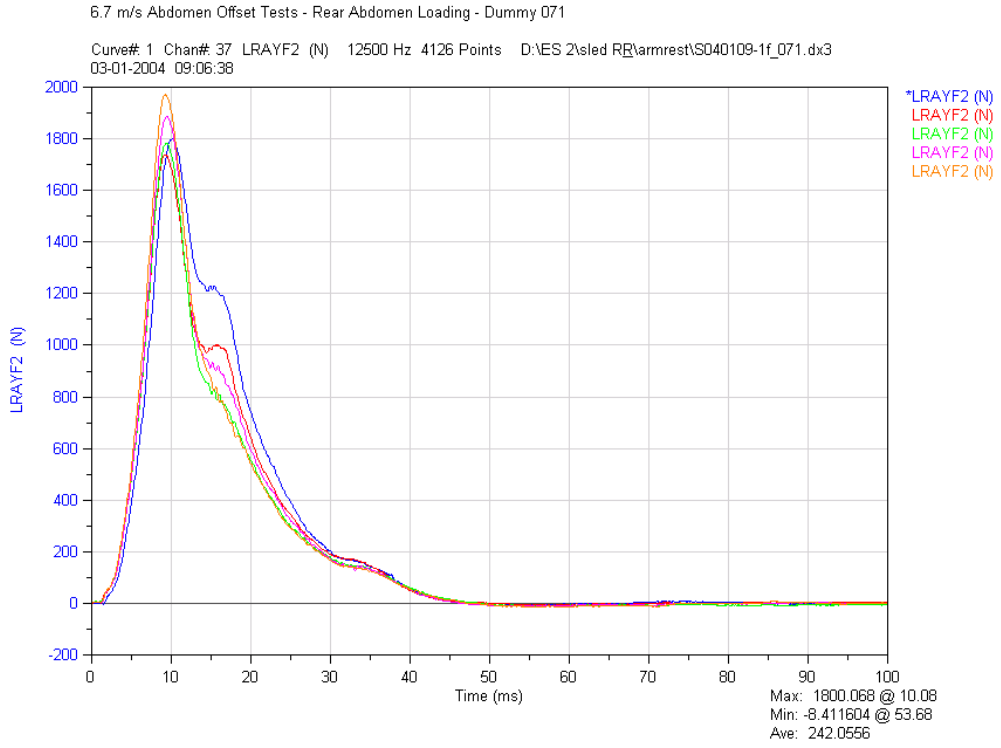

Figure C.15.b. Rear Abdomen Loading – Dummy 071

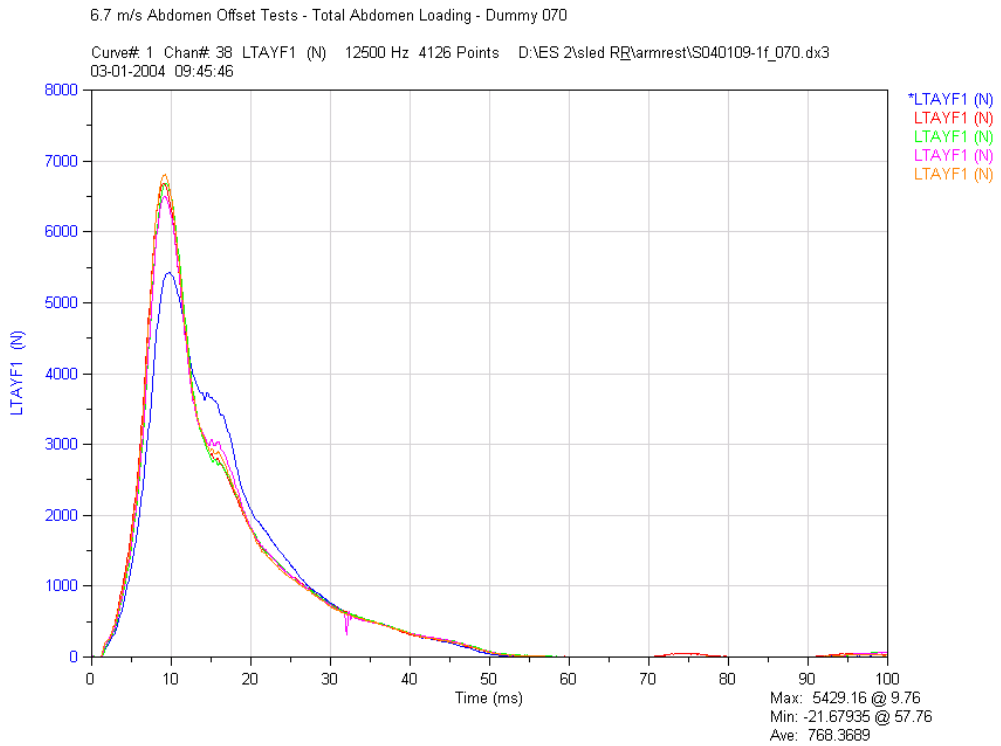

Figure C.16.a. Total Abdomen Loading – Dummy 070

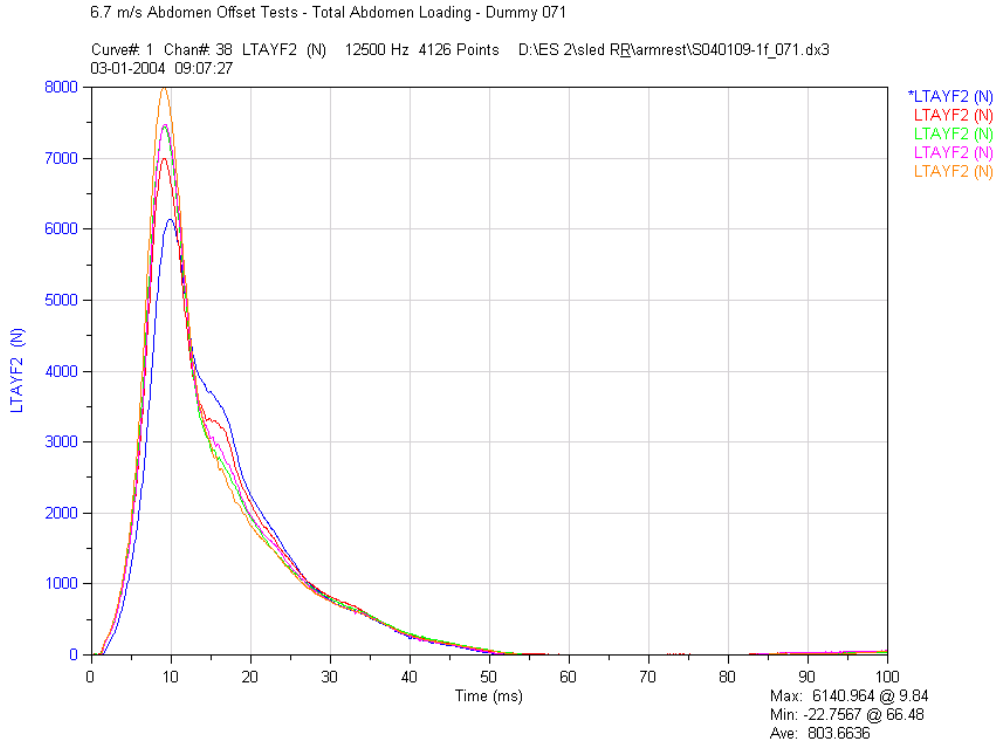

Figure C.16.b. Total Abdomen Loading – Dummy 071

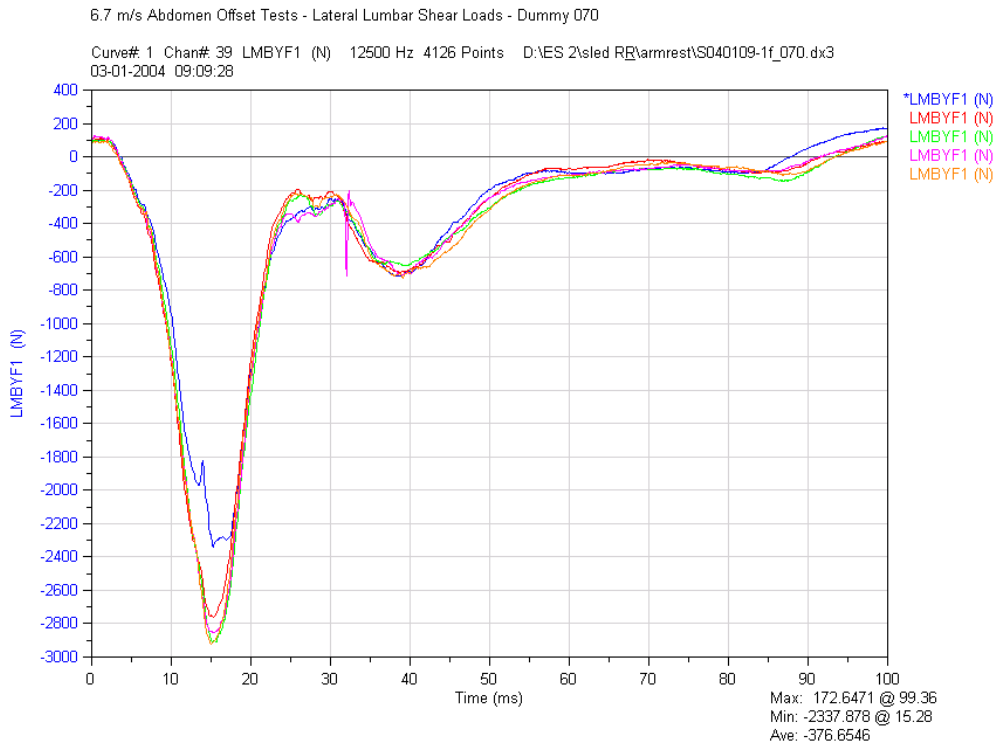

Figure C.17.a. Lumbar Lateral Shear Loads – Dummy 070

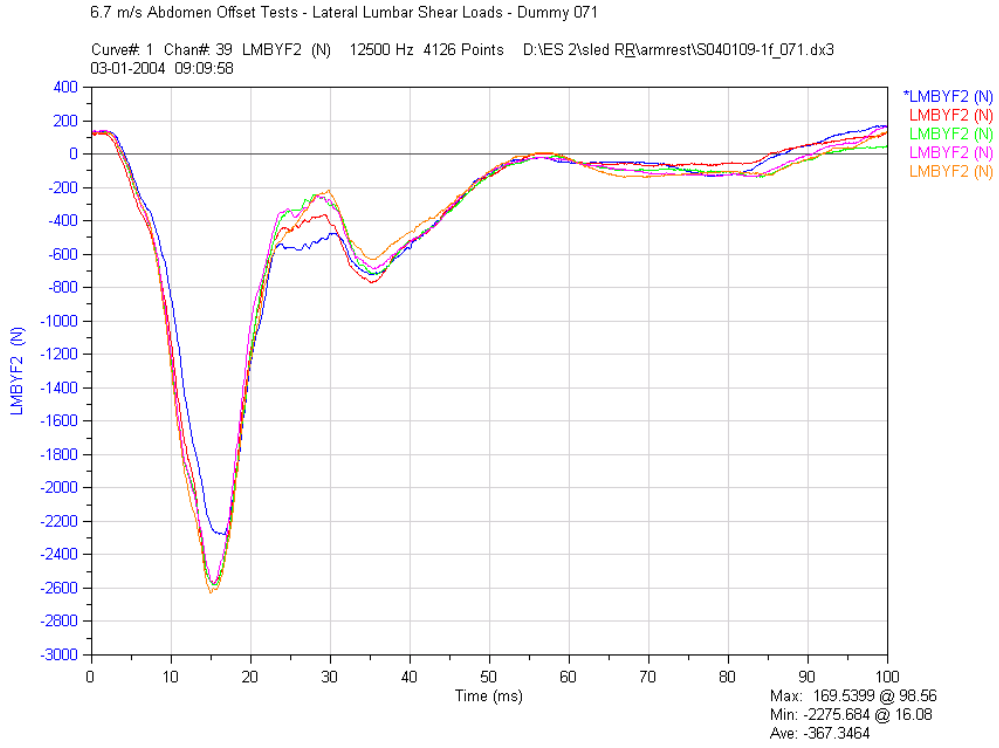

Figure C.17.b. Lumbar Lateral Shear Loads – Dummy 071

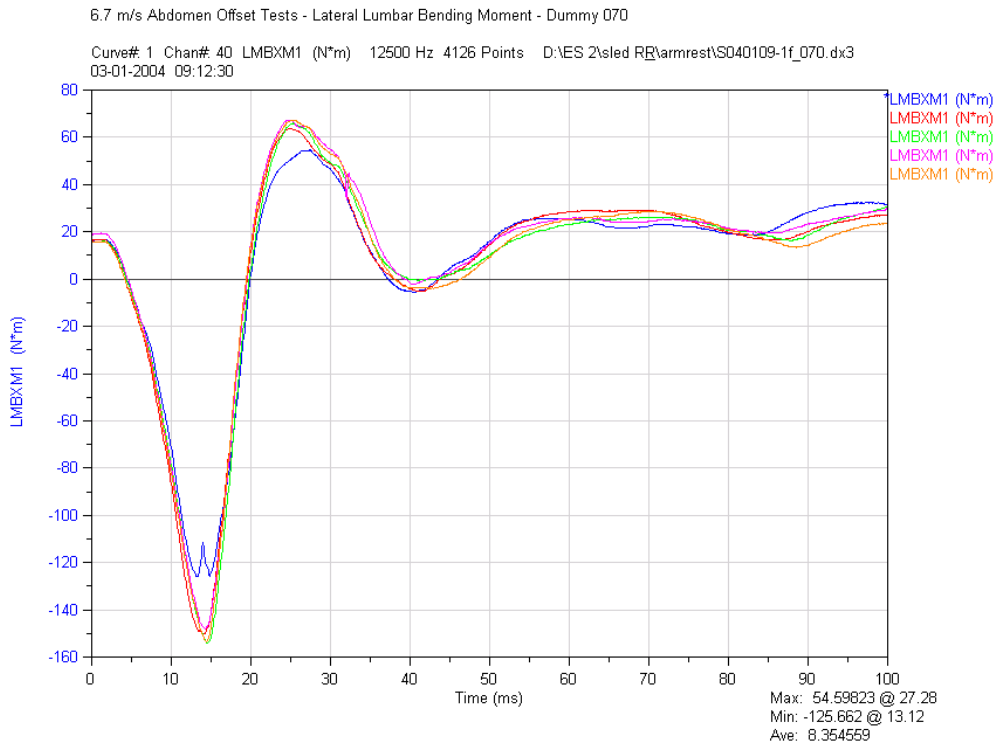

Figure C.18.a. Lumbar Lateral Bending Moment – Dummy 070

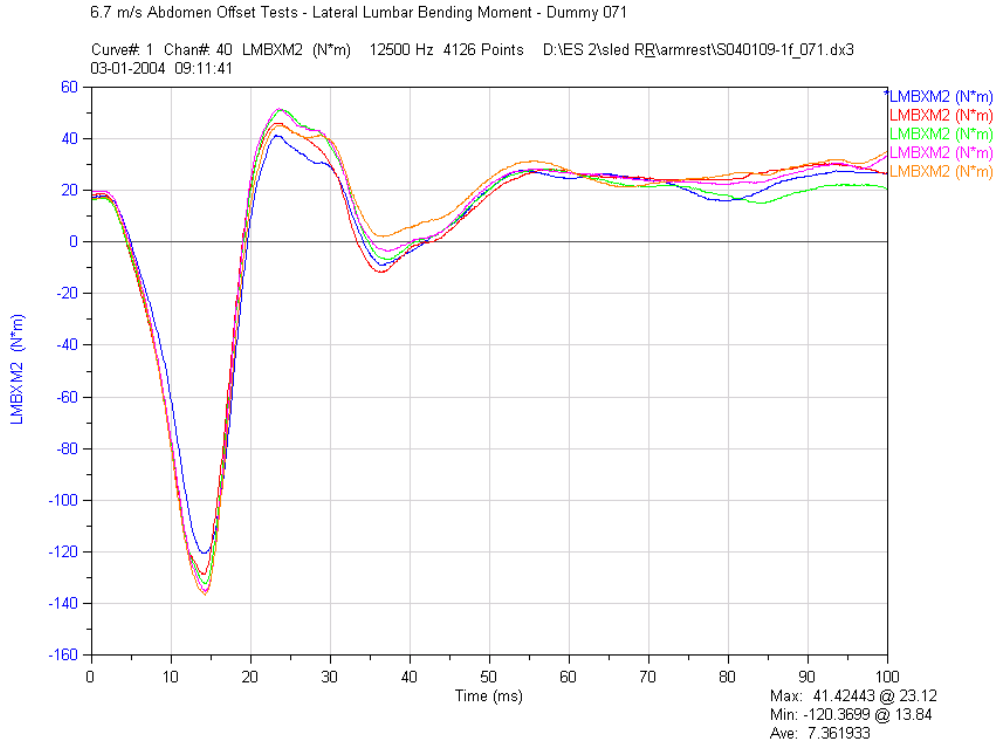

Figure C.18.b. Lumbar Lateral Bending Moment – Dummy 071

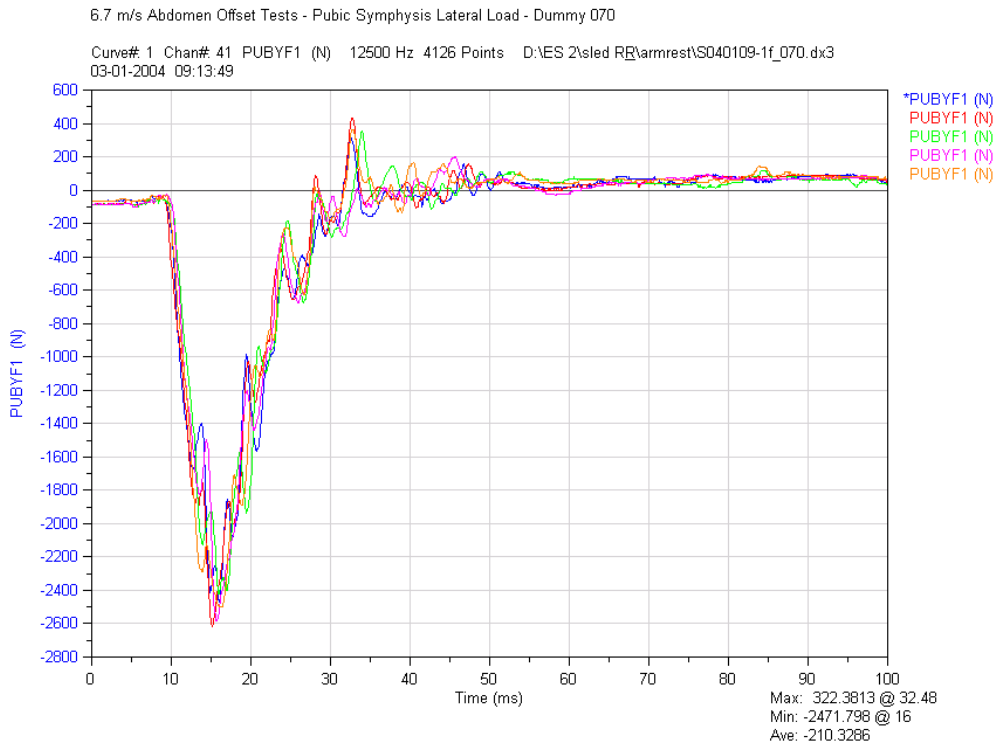

Figure C.19.a. Pubic Symphysis Load – Dummy 070

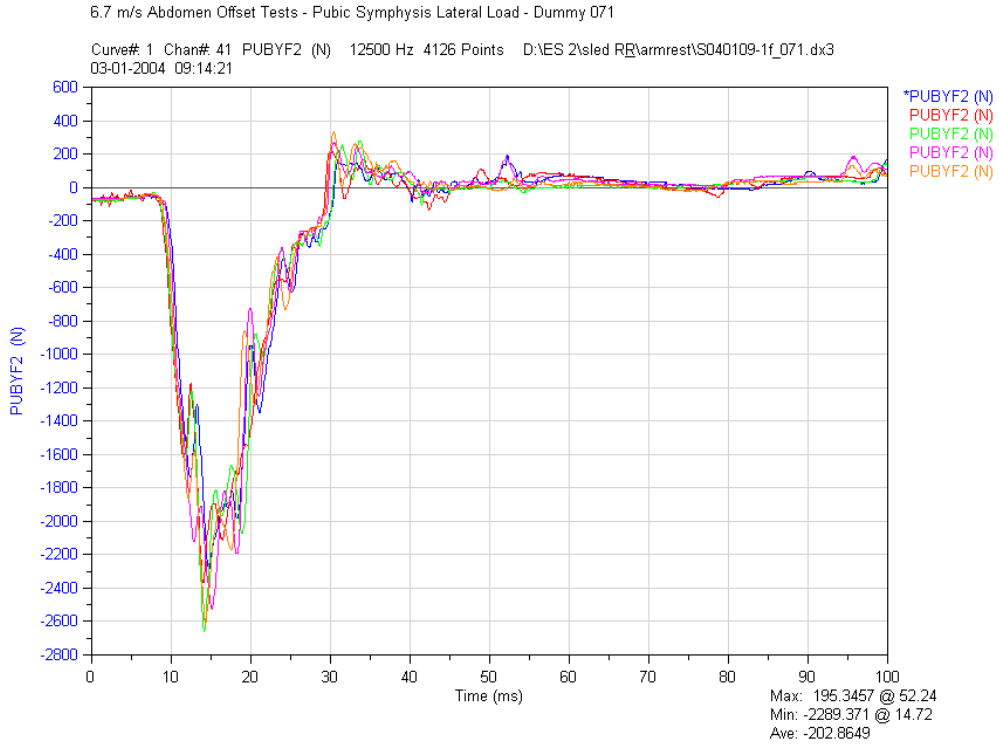

Figure C.19.b. Pubic Symphysis Load – Dummy 071

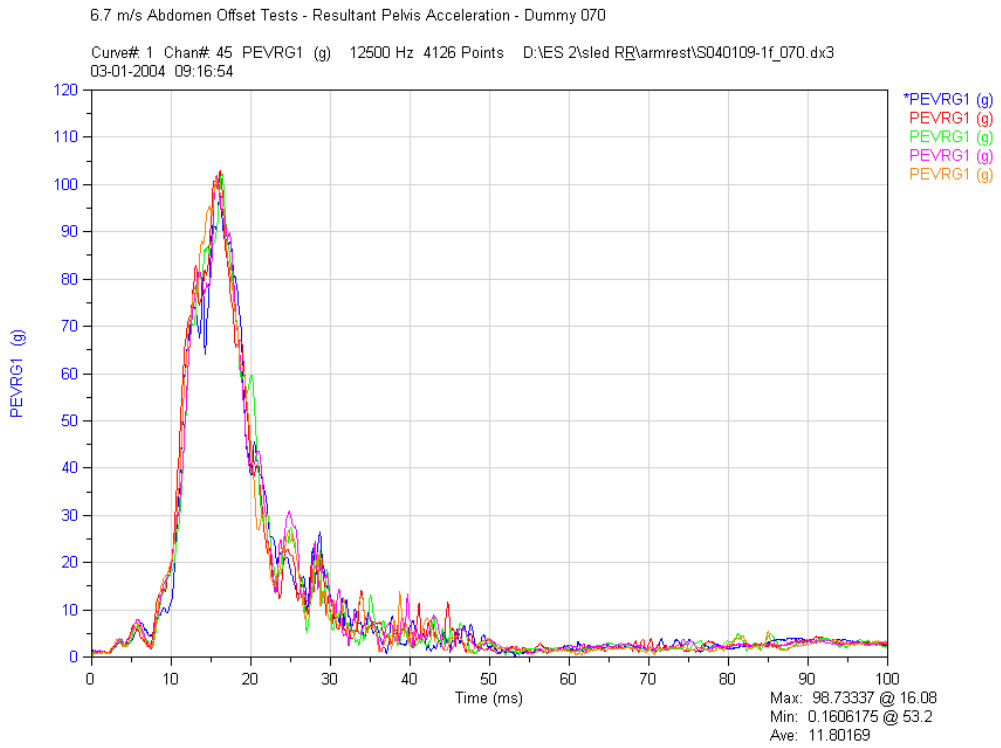

Figure C.20.a. Resultant Pelvis Acceleration – Dummy 070

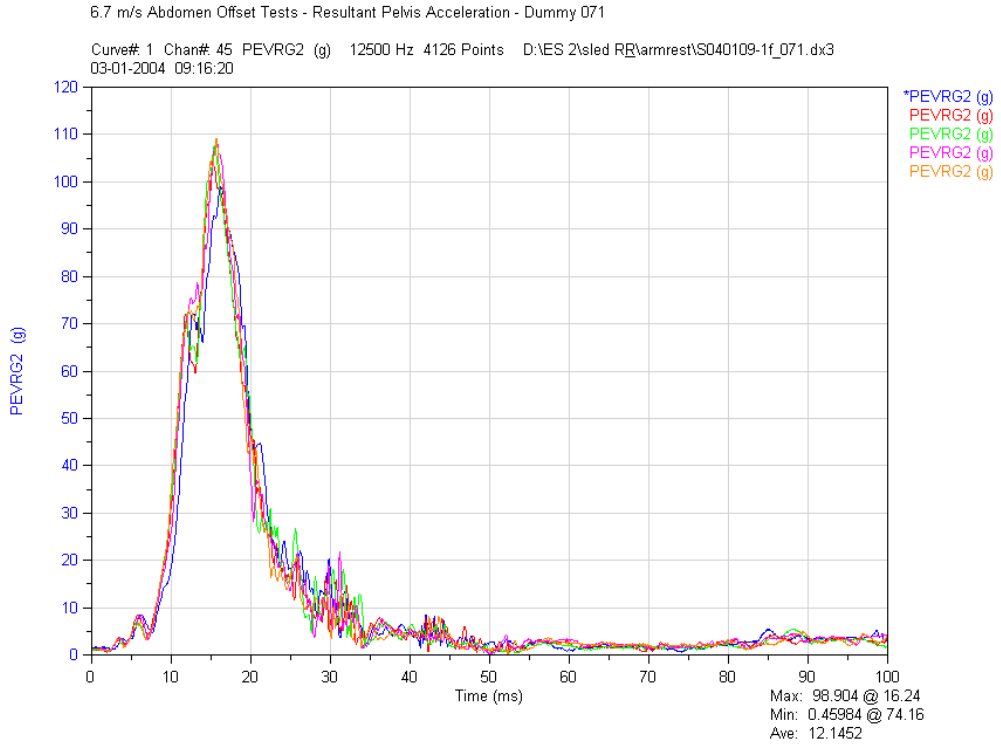

Figure C.20.b. Resultant Pelvis Acceleration – Dummy 071